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PROPOSED

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) BACKGROUND DOCUMENT FOR MERCURY WASTES

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street, S.W.
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1. INTRODUCTION

Pursuant to section 3004(m) of the Resource Conservation and Recovery Act (RCRA), enacted as a part of the Hazardous and Solid Waste Amendments (HSWA) on November 8, 1984, the Environmental Protection Agency (EPA) is proposing treatment standards based on best demonstrated available technology (BDAT) for the following: mercury-containing waste identified in 40 CFR 261.32 as K106; commercial chemical product wastes identified in 40 CFR 261.33 as P065, P092, and U151; and wastes identified in 40 CFR 261.24 as exhibiting the characteristic of leachability for mercury (D009). In addition, the Agency is proposing to revise treatment standards for K071 nonwastewaters, for which treatment standards were originally promulgated with the First Third of RCRA hazardous wastes (53 FR 31137, August 17, 1988); the revised treatment standards for this waste incorporate a total mercury concentration level for K071 wastes that contain recoverable concentrations of mercury.

Compliance with these treatment standards would be a prerequisite for the placement of these wastes in units designated as land disposal units according to 40 CFR Part 268. The effective date of final promulgated treatment standards for these wastes will be May 8, 1990.

This background document presents the Agency's rationale and technical support for developing regulatory treatment standards for the mercury-containing wastes identified above. Section 2 describes the industries affected by regulation of these wastes, explains the processes generating these wastes, and presents available waste characterization data. Section 3 specifies the applicable and demonstrated treatment technologies for these wastes. Section 4 contains performance data for the demonstrated technologies, and Section 5 analyzes these performance data to determine BDAT for each waste. Section 6 presents the rationale for selection of regulated constituents, and Section 7 presents the proposed BDAT treatment standards for the regulated constituents selected for each waste.

EPA's promulgated methodology for developing BDAT treatment standards is described in two separate documents: Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") (USEPA 1988a) and Methodology for Developing BDAT Treatment Standards (USEPA 1989a). The petition process to be followed in requesting a variance from the BDAT treatment standards is discussed in the methodology document.

The Agency classifies hazardous wastes as either wastewaters or nonwastewaters. For the purpose of determining the applicability of the proposed treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Wastes not meeting this definition must comply with the proposed treatment standards for nonwastewaters.

For all mercury-containing wastewaters for which treatment standards are being proposed (D009, K106, P065, P092, and U151), the best demonstrated available technology (BDAT) is chemical precipitation. Treatment standards are based on the performance of sulfide precipitation treatment of K071 wastewaters. Some mercury-containing wastewaters may require more extensive treatment trains in order to treat other metals or organics that may interfere with the treatment of mercury. Pretreatment by an oxidation step (with reagents such as hydrogen peroxide or sodium hypochlorite) or incineration may be necessary to treat the organics in

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* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, the quantity of total suspended solids is measured by Method 209c (Total Suspended Solids Dried at 103°C to 105°C) in Standard Methods for the Examination of Water and Wastewater, 15th Edition (APHA, AWWA, and WPCF 1985).

P092 wastewaters and D009 organomercury wastewaters. Pretreatment by aqueous chemical deactivation or by incineration in specially-designed thermal treatment units may be necessary to treat reactive constituents in P065 wastewaters and reactive D009 wastewaters. The treatment standard for mercury-containing wastewaters is presented in Table 1-1, at the end of this section.

For D009 wastewaters, EPA is proposing two regulatory options. One regulatory option would require treatment of these wastes to comply with a treatment standard that is less than the EP toxic level for mercury. The proposed treatment standard (0.030 mg/l, as shown in Table 1-1) is supported by the performance of chemical precipitation, which has been determined to be BDAT for K106, U151, P065, and P092 wastewaters. The second regulatory option would require treatment of these wastes to meet a treatment level of 0.2 mg/l (the EP toxicity level for mercury). EPA is soliciting comments on the merits of each of these approaches.

For nonwastewater forms of K071, K106, U151, and D009 wastes, EPA is proposing to establish two general mercury subcategories. A total mercury concentration of 16 mg/kg is proposed to classify these mercury wastes into one of these two subcategories and to determine compliance with the proposed treatment standards. The 16 mg/kg cut-off level is based on the retorting/roasting of K071 and K106 wastes. (See Section 7 for a detailed explanation of the derivation of the 16 mg/kg cut-off level.)

For nonwastewater forms of K071, K106, U151, and D009 wastes in the high-mercury subcategory (greater than or equal to 16 mg/kg total mercury), proposed BDAT treatment standards are based on thermal recovery of mercury. The proposed treatment standard is expressed as the use of a thermal recovery technology (roasting or retorting) as a method of treatment. Thermal recovery treatment technologies provide an overall

reduction in both toxicity and mobility of mercury in wastes. EPA is proposing thermal recovery as a treatment method for these wastes to ensure that the treatment standard achieves the environmental benefits associated with recycling technologies.

It is likely that residuals from thermal recovery treatment of the listed mercury wastes will be considered by the Agency to be indigenous wastes to the thermal recovery process. Hence, these wastes would only be considered hazardous if they exhibit the characteristic of EP toxicity for mercury or any other hazardous waste characteristic. Thus, any nonwastewater residue from retorting of a listed hazardous waste that exhibits the characteristic of EP toxicity for mercury and has a total mercury concentration equal to or greater than 16 mg/kg will require treatment to meet the D009 inorganic nonwastewater treatment standard.

For K106, U151, and D009 wastes in the low-mercury subcategory, BDAT has been determined to be acid leaching. EPA is proposing to transfer the performance of acid leaching treatment of K071 wastes to these inorganic mercury nonwastewaters in the low-mercury subcategory. The proposed BDAT treatment standard for these wastes is 0.025 mg/l mercury as measured by the TCLP leachate. Treatment standards for K106 and U151 nonwastewaters are summarized in Table 1-2.

The Agency is proposing to create a new subcategory for K071 wastes identified as the K071 high-mercury subcategory (greater than or equal to 16 mg/kg total mercury). Accordingly, EPA is thus proposing to revise the K071 nonwastewater treatment standard previously promulgated for K071 wastes which now meet the criteria for this high mercury subcategory. For K071 nonwastewaters in the high-mercury subcategory, the proposed treatment standard is retorting or roasting as a method of treatment. The Agency is also proposing to create a second subcategory for K071 nonwastewaters, identified as the K071 low-mercury subcategory, and is

retaining the promulgated K071 treatment standard (0.025 mg/l mercury based on analysis of a TCLP leachate) for these wastes. Treatment standards for K071 nonwastewaters are summarized in Table 1-3.

For P092 nonwastewaters, proposed BDAT treatment standards are based on incineration followed by thermal recovery of mercury from the solid residuals generated from incineration, provided such residues exceed 16 mg/kg total mercury. For P065 nonwastewaters, the proposed BDAT treatment standard is incineration in units designed for treatment of explosive wastes, followed by thermal recovery of mercury from the solid residuals generated by incineration. The proposed treatment standard for these wastes is expressed as a technology standard (incineration) followed by treatment of the wastewater and nonwastewater incineration residuals (scrubber water and incinerator ash) as inorganic mercury wastes. Scrubber waters generated from incineration are classified as P065 and P092 wastewaters by the derived-from rule. For these scrubber waters EPA is proposing the 0.030 mg/l wastewater standard which relies on the same performance data used to develop the existing K071 wastewater standard. Proposed treatment standards for P065 and P092 nonwastewaters are shown in Table 1-4.

The proposed BDAT treatment standard for D009 high-mercury nonwastewaters is a combination of the treatment standards for the high-mercury inorganic nonwastewaters and the organic mercury nonwastewaters. EPA has determined that retorting or roasting represent BDAT for D009 high-mercury nonwastewaters containing elemental mercury or inorganic mercury compounds. However, D009 wastes may contain organomercury constituents or may contain mercury contaminated with organics. Incineration has been determined to be BDAT for organics in this type of D009 nonwastewater and also for nonwastewater organomercury constituents. Since incineration cannot destroy mercury, but instead incineration concentrates mercury in scrubber water or ash to levels not acceptable for land disposal, the Agency is proposing additional

requirements for the mercury in these residuals. As a result the proposed treatment standard for D009 high-mercury nonwastewaters is expressed as either retorting/roasting or incineration followed by retorting or roasting of nonwastewater incineration residuals if these residuals contain recoverable (i.e., greater than 16 mg/kg) concentrations of mercury.

For D009 low-mercury nonwastewaters, BDAT is acid leaching. The proposed treatment standard for these wastes is 0.025 mg/l as measured as a TCLP leachate concentration. The treatment standard is based on the transfer of treatment performance data from acid leaching treatment of K071 wastes. Proposed BDAT treatment standards for D009 nonwastewaters are summarized in Table 1-5.

Information provided to EPA by the U.S. Department of Energy (DOE) indicates the generation of two particular mixed radioactive/hazardous wastes that contain mercury. This information also suggests that the BDAT technologies and standards proposed for the corresponding nonradioactive wastes may not be applicable to these mixed wastes. The Agency has therefore developed alternative treatment standards for these wastes.

One of the mixed wastes identified is waste elemental mercury contaminated with radioactive tritium (a radioisotope of hydrogen). These wastes are often identified as D009 or U151. EPA has determined that recovery technologies do not represent BDAT for this waste because the Agency has no data or information that would indicate that these processes would be able to separate the mercury from the radioactive material, resulting in recovery of reuseable mercury. EPA has identified amalgamation with zinc as a technology that provides significant treatment to these waste in terms of air emissions (thus greatly reducing the toxicity of these wastes) and also potentially reduces the leachability of mercury by amalgamation. The proposed BDAT for these

wastes is amalgamation with zinc, and the proposed treatment standard is amalgamation with zinc as a method of treatment.

The second mixed waste indentified is a waste hydraulic oil contaminated with mercury and radioactive materials (tritium). EPA believes that this waste is amenable to incineration, and has thus determined that incineration reprsents BDAT as it does for the nonradioactive organic mercury nonwastewaters. However, the Agency is proposing to modify the nonradioactive organic mercury nonwastewaters standard for this waste by removing the requirement to recover mercury from the inorganic residues generated from incineration of this waste. Alternatively, the Agency is proposing that nonwastewater incineration residues (incinerator ash and wastewater treatment sludge generated from treatment of incineration scrubber waters) must comply with a TCLP mercury standard of 0.025 mg/l (based on acid leaching as BDAT), and that incineration scrubber waters must meet the 0.030 mg/l total concentration mercury standard proposed for all mercury-containing wastewaters. Proposed treatment standards for mixed radioactive/hazardous mercury wastes are presented in Tables 1-6 and 1-7.

Table 1-1 Proposed BDAT Treatment Standard for D009, K106, P065, P092, and U151 Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Mercury	0.030

Table 1-2 Proposed BDAT Treatment Standards for K106 and U151 Nonwastewaters

High-Mercury Subcategory - Greater than or equal to 16 mg/kg total mercury

ROASTING OR RETORTING AS A METHOD OF TREATMENT	
Low-Mercury Subcategory - Less than 16 mg/kg total mercury	
Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 1-3 Proposed Revised BDAT Treatment Standards for K071 Nonwastewaters

High-Mercury Subcategory - Greater than or equal to 16 mg/kg total mercury

ROASTING OR RETORTING AS A METHOD OF TREATMENT	
Low-Mercury Subcategory - Less than 16 mg/kg total mercury	
Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 1-4 Proposed BDAT Treatment Standards for P065 and P092 Nonwastewaters

INCINERATION FOLLOWED BY ROASTING OR RETORTING OF INCINERATOR NONWASTEWATER RESIDUALS (ASH AND WASTEWATER TREATMENT SLUDGES FROM TREATMENT OF THE INCINERATOR SCRUBBER WATERS) PROVIDED SUCH RESIDUES EXCEED 16 MG/KG TOTAL MERCURY CONCENTRATION

P065 wastes must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, in specially-designed incinerators. The incinerator ash residual must be processed for mercury recovery using a thermal recovery technology if it does not meet the total composition treatment standard.

P092 wastes must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, or burned in boilers or industrial furnaces in accordance with applicable regulatory standards. The incinerator ash residual must be processed for mercury recovery using a thermal recovery technology if it does not meet the total composition treatment standard.

Table 1-5 Proposed BDAT Treatment Standards for D009 Nonwastewaters

High-Mercury Subcategory - Greater than or equal to 16 mg/kg total mercury

ROASTING OR RETORTING AS A METHOD OF TREATMENT; OR INCINERATION[a] AS A METHOD OF TREATMENT FOLLOWED BY ROASTING OR RETORTING OF THE INCINERATOR NONWASTEWATER RESIDUES (ASH AND WASTEWATER TREATMENT SLUDGES FROM TREATMENT OF THE INCINERATOR SCRUBBER WATERS) PROVIDED SUCH RESIDUES EXCEED 16 MG/KG TOTAL MERCURY CONCENTRATION

[a] Organic nonwastewater forms of this waste must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, or burned in boilers or industrial furnaces in accordance with applicable regulatory standards. Reactive nonwastewater forms of this waste must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, in specially-designed incinerators. The incinerator ash residual must be processed for mercury recovery using a thermal recovery technology if it does not meet the total composition treatment standard.

Low-Mercury Subcategory - Less than 16 mg/kg total mercury

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 1-6 Proposed BDAT Treatment Standards for D009 and U151
Elemental Mercury Contaminated with Radioactive Materials

AMALGAMATION WITH ZINC AS A METHOD OF TREATMENT

Table 1-7 Proposed BDAT Treatment Standards for D009 Hydraulic Oil Contaminated with Mercury and Radioactive Materials

INCINERATION AS A METHOD OF TREATMENT WITH INCINERATOR RESIDUES MEETING THE FOLLOWING: (1) ASH AND WASTEWATER TREATMENT SLUDGES FROM TREATMENT OF THE INCINERATOR SCRUBBER WATERS MUST COMPLY WITH A TCLP MERCURY CONCENTRATION OF 0.025 MG/L; and (2) SCRUBBER WATERS MUST COMPLY WITH A TOTAL MERCURY CONCENTRATION OF 0.030 MG/L (WASTEWATER STANDARD)

The U and P wastes of concern (U151, P065, and P092) are generated as discarded chemical products, off-specification products, container residues, or contaminated soil, water, or other debris resulting from the cleanup of leaks or spills of products or off-specification products. This background document addresses the development of treatment standards for P065, P092, and U151.

This document also discusses the development of treatment standards for wastes listed in 40 CFR Section 261.24 as D009. D009 is any waste that is characteristically hazardous based on the concentration of mercury in the leachate as determined by the EP Toxicity Leaching Procedure. D009 wastes can be generated in many different forms by many different industrial processes.

2.1 Industries Affected and Process Descriptions

Metallic mercury and inorganic and organic mercury compounds are used in many industries. Figure 2-1 summarizes the manufacturing process chemistry and end uses of the industrially-important mercury compounds. Table 2-1 presents the major end users of mercury and their mercury consumption in 1983.

The largest use of mercury, amounting to 48 percent of all mercury used in 1983 (the last year for which statistics were available) is in the manufacture of mercuric oxide batteries, primarily the mercuric oxide/zinc dry cell. Mercuric oxide is used as the cathode material in these batteries. Metallic mercury is often amalgamated with other metals (e.g., silver and zinc) and used as the anode material in batteries. The production of batteries using mercury and mercuric oxide is discussed in Section 2.1.1.

The second largest use of mercury, amounting to 16 percent of that used in 1983, is in the manufacture of chlorine by the mercury cell

2. INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

As discussed in Section 1, those wastes listed in 40 CFR Sections 261.24, 261.32, and 261.33 are subject to the land disposal restriction provisions of RCRA. This document discusses the mercury-containing wastes K071, K106, P065, P092, U151, and D009. This section describes the industries affected by land disposal restrictions for these mercury-containing wastes and the processes generating the wastes, summarizes available waste characterization data, and discusses applicable treatability groups.

Within the industry-specific listing of hazardous wastes in Section 261.32 are the following three wastes generated by the chlorine industry:

K071: Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.

K073: Chlorinated hydrocarbon waste from the purification step of the diaphragm cell process using graphite anodes in chlorine production.

K106: Wastewater treatment sludge from the mercury cell process in chlorine production.

The listed waste K071 has been regulated previously with the First Third of restricted wastes. Nonwastewater treatment standards for this waste are being revised in this document. This background document addresses the development of treatment standards for K106 and the reproposed treatment standards for K071 nonwastewaters. The listed waste K073 is discussed in a separate Third Third background document (USEPA 1989c).

The following wastes are listed in 40 CFR Section 261.33 for mercury:

P065: Mercury fulminate

P092: Phenylmercuric acetate

U151: Mercury

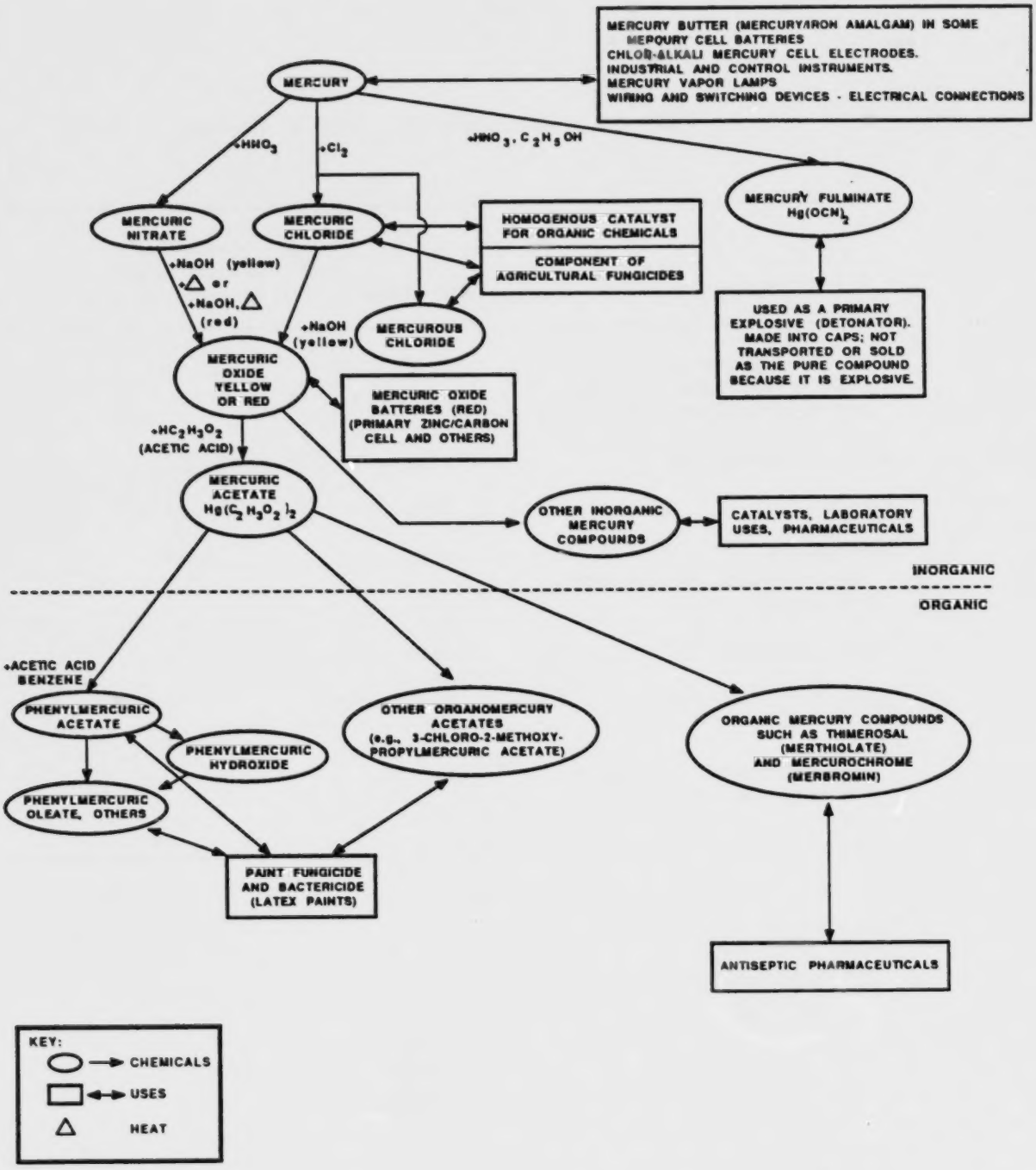

FIGURE 2-1. MERCURY CHEMICALS AND PRIMARY USES

Table 2-1 Major Industrial Uses of Mercury

Industry	SIC Codes	Amount of mercury used (thousands of lb)
Electrical products (batteries, lamps, wiring and switching devices, etc.)	3600	2,050
Chlorine production	2812	612
Paints	2851	460
Instruments (thermometers, manometers, barometers, etc.)	3820	187
Dental supplies	3843	121
Catalysts, miscellaneous	2819, 2869	36.8
Other (pharmaceuticals, pigments, lab analyses, etc.)	2833, 2816, others	270

Reference: U.S. Bureau of Mines 1985.

process. Metallic mercury is used in this process as the cathode material in electrolytic cells that decompose a sodium chloride brine solution into sodium hydroxide and chlorine. This process is discussed in Section 2.1.2.

The next largest use of mercury is as a fungicide and bactericide in latex paints. The primary compound used in this application is phenylmercuric acetate. Other organic mercury compounds are also used. Phenylmercuric acetate is made from mercuric acetate, as shown in Figure 2-1.

Other uses of mercury metal are in electrical equipment such as industrial control instruments, in mercury vapor lamps, in wiring and switching devices as an electrical connection, and in barometers and thermometers. Mercury compounds are also used as primary explosives (mercury fulminate), as homogeneous catalysts (mercuric chloride), as components of agricultural fungicides (mercurous chloride and mercuric chloride), and as antiseptic pharmaceuticals (various organic and inorganic mercury compounds).

2.1.1 Manufacture of Mercury Batteries

Many batteries contain metallic mercury or mercuric oxide as components. Mercury cell batteries (mercuric oxide:zinc cells) consist of a mercuric oxide powder as the cathode, a mercury/zinc amalgam as the anode, and an alkaline electrolyte solution (usually potassium hydroxide). Mercuric oxide is also used in other types of batteries as a cathode material. Both nonwastewaters and wastewaters containing mercury can be generated from battery manufacturing. Wastewaters containing mercury can be generated from cleanup of spills of mercuric oxide or metallic mercury or as water washes of processing equipment. Nonwastewaters that can be generated include off-specification batteries,

spilled or off-specification mercuric oxide, spilled mercury, or wastewater treatment sludges generated from the treatment of mercury-containing wastewaters.

2.1.2 Chlorine Production by the Mercury Cell Process

Chlorine is produced primarily from the electrolytic decomposition of either sodium chloride or potassium chloride, from which the coproducts are sodium hydroxide (caustic soda) or potassium hydroxide. All of the caustic soda and potassium hydroxide and over 90 percent of the chlorine produced in the U.S. are made by the electrolytic decomposition of sodium chloride or potassium chloride. Chlorine is also produced by other processes, including non-electrolytic oxidation of hydrochloric acid (HCl), from the production of sodium metal, and from electrolytic production of magnesium metal from molten magnesium chloride.

Three types of electrolytic cells are in commercial use for the production of alkalies and chlorine: the mercury cell, the diaphragm cell, and the membrane cell. The listed wastes K071 and K106 are generated in chlorine production by the mercury cell process. The Agency estimates that there are 20 facilities that produce chlorine by the mercury cell process and may generate K106 waste. EPA also estimates that 14 of these facilities do not use prepurified salt, and thus also may generate K071 waste. The locations of these facilities are provided in Table 2-2, listed by State, and in Table 2-3, listed by EPA Region. Chlorine producers fall under SIC Code 2812, Alkalies and Chlorine.

In chlorine production by the mercury cell process, a saturated salt brine solution is prepared by dissolving sodium chloride, usually in the form of rock salt (although prepurified salt is sometimes used), in the depleted brine solution recycled from the mercury cells (see Figure 2-2). The brine is purified (unless prepurified salt is used) by addition of sodium carbonate and sodium hydroxide to precipitate any

Table 2-2 Number of Producers of Chlorine Using the Mercury Cell Process Listed by State

State	Number of producers	Number that do not use prepurified salt
Alabama (IV)	3	3
Delaware (III)	1	1
Georgia (IV)	2	1
Kentucky (IV)	1	1
Louisiana (VI)	2	1
Maine (I)	1	1
New York (II)	2	1
North Carolina (IV)	1	1
Ohio (V)	1	1
Tennessee (IV)	1	1
Texas (VI)	1	0
Washington (X)	1	1
West Virginia (III)	2	0
Wisconsin (V)	1	1
Total	20	14

Reference: SRI 1989.

Table 2-3 Number of Producers of Chlorine Using the Mercury Cell Process Listed by EPA Region

EPA Region	Number of producers	Number that do not use prepurified salt
I	1	1
II	2	1
III	3	1
IV	8	7
V	2	2
VI	3	1
X	1	1
Total	20	14

Reference: SRI 1989.

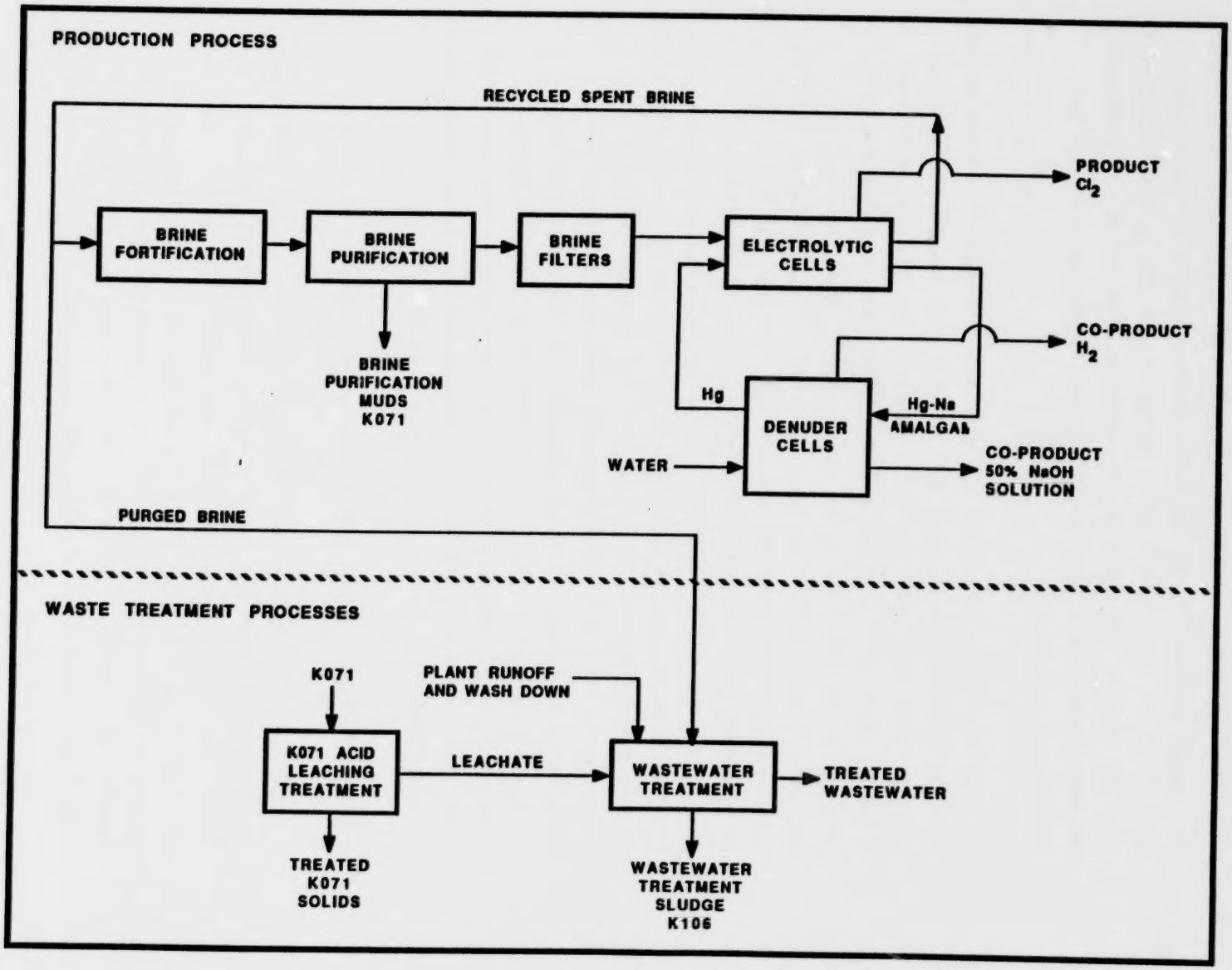

FIGURE 2-2. PROCESSES GENERATING K071 AND K106 WASTES

dissolved impurities. Solids (muds) generated in brine purification are the listed waste K071. The purified saturated brine is fed to the mercury cells, where electrolytic decomposition into sodium hydroxide and chlorine occurs. The chlorine is subsequently purified. If potassium chloride is used as a feed to the process, potassium hydroxide and chlorine are produced.

Sources of wastewater from the production of chlorine by the mercury cell process include (1) brine that is bled from the end boxes of the mercury cells, (2) wastewater collected from the floor of or basement below the room containing the mercury cells, generated from periodic washdown of the cell room floor and equipment, and (3) any other wastewaters generated by the plant that may contain mercury, including wastewaters generated during dewatering or treatment of K071 waste. Treatment of plant process wastewaters by chemical precipitation generates a wastewater treatment sludge, which is the listed waste K106. With the exception of one mercury-cell chlorine production facility, K106 is generated by sulfide precipitation. One facility currently uses hydrazine to treat mercury-contaminated wastewaters; this process generates a mercurous hydroxide compound. In the past, K106 was generated by chemical reduction treatment of mercury-contaminated wastewaters using sodium borohydride, but EPA believes that this compound is no longer used to treat mercury-contaminated wastewaters generated in chlorine production by the mercury cell process.

2.1.3 Manufacture and Use of Organomercury Fungicides and Bactericides

The Agency has information that phenylmercuric acetate (P092) and phenylmercuric oleate are produced by Cosan Chemical in Carlstadt, New Jersey (SRI 1989). These compounds (and other phenylmercury compounds) are used as bactericides in latex paint formulations. Phenlymercuric acetate is manufactured by reaction of mercuric acetate with benzene. Phenylmercuric acetate can be used as a starting material in the production of many other phenylmercury compounds.

In paint formulation operations, pigments are mixed with solvents, carriers, and other additives. Phenylmercury compounds are added in very small quantities (less than 1 percent) as preservatives for latex paints. Washing of equipment used in paint formulation may result in the generation of wastes containing organomercury compounds such as phenylmercuric acetate. These wastes sometimes contain other organic compounds as well.

2.2 Waste Characterization

2.2.1 K071

K071 characterization data are presented in the BDAT Background Document for K071 (USEPA 1988b). This waste was found to consist of primarily inorganic solids and water, with a mercury content of less than 100 ppm as metallic mercury and soluble mercuric chloride.

2.2.2 K106

EPA has waste characterization data for both K106 generated by sulfide treatment and K106 generated by hydrazine treatment. The approximate concentrations of the major constituents for both of these K106 forms were determined from EPA analysis of the waste and other characterization data and information submitted by industry to EPA. As summarized in Table 2-4, both forms of K106 are primarily composed of water and diatomaceous earth filter aid. The K106 generated by sulfide precipitation contains approximately 4.4 percent mercury, as mercuric sulfide; the K106 generated by hydrazine treatment contains approximately 0.5 percent mercury, as mercurous hydroxide.

Table 2-4 Waste Composition Data for Untreated K106 Wastes

Constituent	Untreated K106 waste concentration (mg/kg) (a)	(b)	(c)	(c)	(c)
BOAT List Metals					
Antimony	<3.8	-	-	-	-
Arsenic	1.1	-	-	-	-
Barium	74	-	-	-	-
Beryllium	<0.1	-	-	-	-
Cadmium	2.3	-	-	-	-
Chromium	6.3	-	-	-	-
Copper	133	-	-	-	-
Lead	50	-	-	-	-
Mercury	25,900	2000 - 150,000	4300 - 17,000	55,000 - 146,000	5000 - 7000
Nickel	14	-	-	-	-
Selenium	<5.0	-	-	-	-
Silver	131	-	-	-	-
Thallium	<8.6	-	-	-	-
Vanadium	0.46	-	-	-	-
Zinc	443	-	-	-	-
Other Analyses					
Aluminum	168	-	-	-	-
Calcium	478	-	-	-	-
Cobalt	1.3	-	-	-	-
Iron	833	-	400	-	-
Magnesium	132	-	-	-	-
Manganese	6.5	-	-	-	-
Potassium	7,870	-	-	-	-
Sodium	4,120	-	-	-	-
Tin	<5.5	-	-	-	-
Sulfide	-	-	-	-	-
Total solids	41.5	-	-	-	-
Total suspended solids	-	-	-	-	-
Paint filter test	Pass	-	-	-	-
Diatomaceous earth	-	-	700,000 - 950,000	800,000 - 950,000	-
Water	-	-	5000 - 20,000	50,000 - 150,000	-
Sodium chloride	-	-	80,000 - 100,000	-	-

- = Not analyzed.

References: (a) USEPA 1988c.
(b) Versar 1986a.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration (mg/kg)					
	(d)		(d)		(d)	
	Total	TCLP (mg/l)	Total	EP Toxicity (mg/l)	Total	TCLP (mg/l)
BOAT List Metals						
Antimony	<52	0.175	-	-	<0.005	<0.005
Arsenic	52	<0.076	0.7	0.003	0.407	0.018
Barium	119	0.551	6.0	0.06	175	0.12
Beryllium	<1.4	<0.004	2.3	-	<1.5	<0.005
Cadmium	15	0.03	2.3	0.03	5.0	<0.01
Chromium	223	0.128	4.6	0.024	36	<0.01
Copper	861	<0.032	-	-	345	0.07
Lead	456	1.59	111	-	135	0.05
Mercury	62,500	0.045	-	0.006	38,300	2.73
Nickel	138	0.681	1.0	0.045	260	<0.01
Selenium	1.7	<0.05	0.3	0.001	<0.005	<0.005
Silver	12	<0.02	2.8	0.0027	10	<0.01
Thallium	-	-	-	-	<5	<0.05
Vanadium	9.0	<0.016	-	-	<5	<0.02
Zinc	3940	15.2	-	-	128	0.05
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	-	-	-	-	7,493	196
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	50,000	-	540,000	-	440,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	-	-	5910	-	<60	-
Sulfate	-	-	3090	-	5.0	-
Total organic carbon	-	-	-	-	-	-
Oil and grease	-	-	9.6	-	4495	-

- = Not analyzed.

References: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration (mg/kg)					
	(d)		(d)		(d)	
	Total	TCLP (mg/l)	Total	EP Toxicity (mg/l)	Total	EP Toxicity (mg/l)
BDAT List Metals						
Antimony	<6	<0.06	-	-	0.2	-
Arsenic	8.0	0.14	3.0	<0.005	0.1	0.01
Barium	71	0.21	5.0	<0.03	3.0	2.5
Beryllium	<0.2	<0.002	-	-	-	-
Cadmium	2.0	<0.005	0.4	<0.005	-	0.01
Chromium	70	<0.007	750	0.6	3.0	0.01
Copper	361	<0.03	-	-	250	-
Lead	142	<0.05	4.0	<0.5	100	0.25
Mercury	161,000	3.88	20,000	<0.0005	5,000	5.0
Nickel	167	1.16	34	0.09	100	-
Selenium	<2	<0.05	4.0	<0.005	-	0.05
Silver	4.0	<0.005	1.0	<0.007	-	0.1
Thallium	<5	<0.05	-	-	-	-
Vanadium	<4	<0.04	-	-	-	-
Zinc	405	3.04	-	-	250	-
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	1590	1.2	<11	-	-	-
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	690,000	-	580,000	-	500,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	47,000	-	-	-	-	-
Sulfate	19,100	-	-	-	-	-
Total organic carbon	39,600	-	-	-	-	-
Oil and grease	3400	-	22,500	-	-	

- = Not analyzed.

References: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration (mg/kg)					
	(d)		(d)		(d)	
	Total	EP Toxicity (mg/l)	Total	EP Toxicity (mg/l)	Total	TCLP (mg/l)
BOAT List Metals						
Antimony	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-
Barium	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-
Cadmium	-	-	-	-	-	-
Chromium	-	-	-	-	-	-
Copper	-	-	-	-	-	-
Lead	-	-	-	-	-	-
Mercury	28,347	0.399	4098	2.26	23,004	1.25
Nickel	-	-	-	-	-	-
Selenium	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Thallium	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-
Zinc	-	-	-	-	-	-
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	-	-	-	-	-	-
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	290,000	-	-	-	400,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-
Oil and grease	-	-	-	-	-	

- = Not analyzed.

References: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

Table 2-4 (continued)

Constituent	Untreated K106 waste concentration (mg/kg)					
	(d)		(d)		(d)	
	Total	EP Toxicity (mg/l)	Total	EP Toxicity (mg/l)	Total	EP Toxicity (mg/l)
BOAT List Metals						
Antimony	-	-	-	-	-	-
Arsenic	<100	<0.005	-	<0.1	0.55	0.012
Barium	1300	1.32	-	0.12	-	0.07
Beryllium	-	-	-	-	-	-
Cadmium	<100	<0.01	-	<0.01	6.5	<0.1
Chromium	<100	<0.01	-	0.06	2.46	<1
Copper	-	-	-	-	-	-
Lead	400	0.05	-	<0.1	204	0.5
Mercury	10,100	0.113	25,000	0.08	-	<0.1
Nickel	-	-	-	-	89	1.0
Selenium	<100	<0.005	-	<0.1	90	-
Silver	<100	<0.01	-	<0.01	70	<0.3
Thallium	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-
Zinc	-	-	-	-	-	-
Other Analyses						
Aluminum	-	-	-	-	-	-
Calcium	-	-	-	-	-	-
Cobalt	-	-	-	-	-	-
Iron	-	-	-	-	-	-
Magnesium	-	-	-	-	-	-
Manganese	-	-	-	-	-	-
Potassium	-	-	-	-	-	-
Sodium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Sulfide	<0.1	-	<0.016	-	-	<1.0
Total solids	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-
Paint filter test	-	-	-	-	-	-
Diatomaceous earth	-	-	-	-	-	-
Water	650,000	-	-	-	450,000	-
Sodium chloride	-	-	-	-	-	-
Chloride	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-
Total organic carbon	-	-	-	-	-	-
Oil and grease	-	-	-	-	1270	-

- = Not analyzed.

References: (a) USEPA 1988c.
(b) Versar 1986.
(c) USEPA 1985.
(d) The Chlorine Institute 1988.

2.2.3 P065

The Agency does not have data or information on the characterization or treatment of P065 wastes. Analysis of the 1986 National Survey of Treatment, Storage, Disposal, and Recycling Facilities (TSDR Survey, USEPA 1986a) and the 1986 National Survey of Hazardous Waste Generators (Generator Survey, USEPA 1986b) data bases indicates that no facilities generated or treated P065 wastes in 1986. As of 1984, the U.S. Army reported that mercury fulminate is no longer used by the U.S. military as an initiating compound in explosives because of poor stability (U.S. Army 1984).

2.2.4 P092

The Agency has no data on the composition of P092 (phenylmercuric acetate) wastes. However, EPA does have data from the one manufacturer identified in Section 2.1.3 on the composition of a wastewater generated in production of this chemical (a D009 waste). Characterization data for this waste are presented in Table 2-5. EPA expects phenylmercuric acetate to be the primary constituent of P092 wastes.

2.2.5 U151

EPA has data from the Generator Survey on the composition of U151 wastes (USEPA 1986b). These data show that of the U151 wastes that are reported as a single waste code (i.e., not mixed with other listed or characteristic wastes), a majority have mercury concentrations greater than 50 percent. EPA expects that the principal constituent of most U151 wastes is metallic mercury.

2.2.6 D009

Characterization data for D009 wastes generated in the organomercury chemicals and battery manufacturing industries are presented in Table 2-5. EPA also has data from the Generator Survey on the composition of D009 wastes (USEPA 1986b). These data show that D009 wastes may contain organic compounds (usually when mixed with solvent wastes). Also, some wastes generated in the production of organomercury compounds for fungicide/bactericide and pharmaceutical uses and generated in organic chemicals manufacturing where mercuric chloride catalyst is used may contain mercury in an organic waste matrix. The mercury concentrations of D009 wastes range from less than 1 ppm to greater than 75 percent. From these Generator Survey data, the Agency concludes that the characteristics of D009 wastes are extremely diverse, depending on the industry and process generating the waste, and therefore that D009 wastes may have similar characteristics to any of the other mercury waste groups.

2.3 Determination of Waste Treatability Groups

EPA has evaluated the characteristics of the K-, P-, D-, and U-code mercury wastes and the processes generating these wastes to determine whether any wastes or groups of wastes can be treated to similar levels using the same technology. If so, these wastes could be classified as a single treatability group.

In some cases, wastes classified under the same waste code (e.g., wastewater and nonwastewater forms of the same waste) may not be treatable to the same concentrations using the same technology or may require different treatment technologies. For example, characteristic wastes (i.e., D-code wastes) may have the same waste code but be generated in different processes in a specific industry or in different industries. This can result in the wastes having different waste

Table 2-5 Waste Composition Data for D009 Wastes

Constituent	Untreated D009 Waste Concentration (units) (a) Total (mg/l)	(b) Total (mg/kg)	(b) TCLP (mg/l)	(c) Total (mg/kg)	(c) TCLP (mg/l)
BDAT List Metals					
Antimony	-	<2.4	<0.024	<2.4	<0.024
Arsenic	-	<1.0	<0.01	<1.0	<0.01
Barium	-	0.36	0.006	42	1.1
Beryllium	-	<0.1	<0.001	<0.1	<0.001
Cadmium	-	<0.5	<0.005	6.8	0.306
Chromium (total)	-	4.8	<0.004	5.0	<0.004
Copper	-	2.1	0.024	73	0.128
Lead	-	<0.5	0.016	6.6	0.062
Mercury	100-1,000	974,000*	1,490	27,200	1.83
Nickel	-	2.8	<0.01	11	0.116
Selenium	-	<0.5	<0.005	<0.5	<0.025
Silver	-	1.1	<0.003	111	0.0047
Thallium	-	<1.0	<0.01	<1.0	<0.01
Vanadium	-	<0.4	<0.004	0.67	<0.004
Zinc	-	<0.3	0.032	29,600	627
BDAT List Organics					
Benzene	50-1,000	-	-	-	-
Toluene	0.01-100		-	-	-
Other Analyses					
Total organic carbon	-	10,700	-	6,620	-

* This value is high. The theoretical maximum concentration for pure mercuric oxide (HgO) is 926,000 mg/kg. It is very difficult to analyze such high concentrations of mercury accurately on an instrument designed to detect mercury at ppb levels.

- = Not analyzed

References: (a) Cosan Chemical 1989. Waste generated from manufacture of phenylmercuric acetate.
(b) USEPA 1989d. Mercuric oxide waste from recycling of batteries.
(c) USEPA 1989d. Zinc/Mercury amalgam from battery manufacturing.

characteristics, such that the wastes may not be treatable to similar concentrations using the same technology. In these instances, the Agency may subdivide waste codes into several treatability groups. EPA expects the chemical forms of some D-code wastes, in particular, to be different and to clearly require different treatments or combinations of treatments. For example, inorganic and organometallic compounds containing the same metal frequently require different types of treatment.

The treatability groups defined by the Agency for the mercury wastes K071, K106, P065, P092, U151, and D009 are discussed in the following subsections. As discussed above, D009 wastes can be generated in many different forms and are expected to comprise more than one treatability group. However, some of the D009 waste groups identified have similar treatability characteristics to one of the K, U, or P waste groups. Some subcategories of D009 wastes have thus been combined with the similar K-, U-, or P-code waste or wastes into treatability groups.

2.3.1 Mercury Nonwastewaters

Based on the available waste characterization data, the chemical and physical behavior of mercury compounds upon treatment, and the performance of treatment technologies identified as BDAT, EPA has determined that all mercury nonwastewaters can be narrowed down to two treatability groups: (1) the high mercury group and (2) the low mercury group.

EPA lacks data to define the nature and characteristics of all wastes in these groups. However, the available data suggest that most mercury nonwastewaters that are currently being roasted/retorted contain inorganic mercury. These same data suggest that nonwastewater derived from the treatment of organomercury wastes can also be retorted. Other mercury wastes, however, such as mercury fulminate (P065), may require

pretreatment, such as incineration, or chemical treatment, to convert the wastes to a form more amenable to recovery/recycling.

In absence of other characterization data that can further define those nonwastewaters amenable to roasting/retorting, EPA is proposing 16 mg/kg as a cut-off level to define the high and low mercury treatability groups. Derivation of this cut-off level is discussed in Section 7.2. Inorganic and organic mercury nonwastewater members of these two treatability groups are discussed below.

(1) Inorganic mercury nonwastewaters. EPA has identified certain wastes as inorganic mercury nonwastewaters. These wastes are expected to contain mercury in the metallic form or as inorganic mercury compounds and are not expected to contain significant concentrations of organic compounds. These wastes include waste codes K071, K106, U151, and D009 wastes. P065 (mercury fulminate) wastes and D009 wastes that may be explosive or reactive are discussed under organic mercury nonwastewaters. Mercury fulminate dissociates in water to mercury ions and cyanate ions, and therefore is chemically more similar to inorganic mercury compounds than to organomercury compounds. P065 and other reactive mercury wastes will, however, be discussed with the organic mercury wastes, because similar technologies (e.g., incineration) are expected to result in similar treatment for these wastes.

Inorganic mercury nonwastewaters (K071, K106, U151, and D009 wastes) are amenable to mercury recovery technologies because the mercury is present in the elemental form or as inorganic mercury compounds. However, these wastes have been shown to sometimes contain as little as 1 ppm or less total mercury. Therefore, not all wastes in this treatability group may be amenable to treatment by thermal mercury recovery technologies. Hence, EPA has divided these wastes into the two above mentioned treatability groups: the high-mercury treatability group

and the low-mercury treatability group. This reflects the applicability of mercury recovery technologies to only mercury nonwastewaters containing recoverable concentrations of mercury.

K106 wastes, as generated, contain from 0.5 percent to 16 percent mercury, normally (except for one known generator) in the form of mercuric sulfide (see Table 2-4). Sulfide-containing residuals from wastewater treatment may also be classified as D009 wastes or (by the derived from rule) as K071, U151, P065, or P092.

Mercuric sulfide has the highest decomposition temperature of any of the common mercury compounds (Weast 1977). Because decomposition is the first step in the volatilization of mercury compounds in mercury recovery, these wastes are expected to be the most difficult from which to recover mercury.

Other inoragnic wastes contain mercury either in the elemental form or as nonsulfide compounds. These wastes are expected to be more easily treatable by mercury recovery technologies than are the mercuric sulfide wastes.

K106 nonwastewaters are generated at one mercury cell chlor-alkali facility by treatment of wastewaters using hydrazine as a reducing agent to precipitate mercury as mercuric hydroxide and metallic mercury. The sludges generated from filtration of this wastewater would be expected to contain mercury and mercury oxide or hydroxide compounds.

K071 wastes contain relatively low concentrations of mercury (up to 77 mg/l, USEPA 1988b) in an inorganic waste matrix. Because K071 is generated from the brine purification step in chlorine production by the mercury cell process, this waste is expected to contain mercury either as metallic mercury or as soluble mercuric chloride.

U151 nonwastewaters and some D009 nonwastewaters also contain elemental mercury or inorganic mercury compounds as the primary constituent. The Agency's data on the composition of U151 wastes (summarized in Section 2.2) indicate that the majority of these wastes, when not mixed with other wastes, are composed of greater than 50 percent mercury. D009 wastes containing mercury or nonsulfide inorganic mercury compounds as the major constituent would also be expected to be treatable to similar levels using the same technologies as U151 wastes, K071 wastes, and nonsulfide K106 wastes.

(2) Organic mercury nonwastewaters. These wastes comprise P065 nonwastewaters and P092 nonwastewaters, as well as some D009 nonwastewaters. The Agency expects some D009 nonwastewaters to contain organomercury compounds or mercury in an organic waste matrix. These wastes may be generated from paint formulation, from the manufacture of organomercury pharmaceuticals, and from the use of homogeneous mercury catalysts in the production of organic chemicals. Because of the presence of organomercury compounds (such as phenylmercuric acetate) or organic compounds in the waste, these wastes may require pretreatment (such as incineration) prior to being treated by the same technologies as D009 nonwastewaters containing only inorganic mercury compounds.

P065 wastes and D009 wastes containing explosive mercury compounds may require specially designed incinerators for treatment. EPA has no data on the composition of P065 wastes, but expects mercury fulminate to be the major constituent. Mercury fulminate and mercury azide, both extremely explosive compounds used as explosive initiators, may also be the major constituent of some D009 wastes. The Agency expects that both nonwastewater and wastewater forms of these wastes will be treatable to similar levels as other inorganic nonwastewaters and wastewaters after treatment of these wastes to remove the reactivity hazard.

2.3.2 Radioactive Wastes Containing Mercury

Information provided to EPA by the United States Department of Energy (DOE) indicates the generation of two particular mixed radioactive/hazardous wastes that contain mercury. Treatment technologies applicable to other mercury-containing nonwastewaters may not be applicable to treatment of these wastes. The Agency, therefore, has established two separate treatability groups for radioactive wastes containing mercury, which are discussed below.

In the nuclear industry, elemental mercury found in vacuum pumps. manometers, and other instruments may be contaminated with radioactive tritium (a radioisotype of hydrogen). These wastes are often identified as D009 or U151. The Agency has no data or information indicating that recovery processes applicable to treatment of other inorganic mercury nonwastewaters would be able to separate the mercury from the radioactive material and recover reusable mercury. These wastes thus represent a separate treatability group from other inorganic high-mercury nonwastewaters.

The DOE also indicated the generation of a hydraulic oil contaminated with mercury and tritium. This waste is expected to be similar to the organic mercury nonwastewaters identified in Section 2.3.2 above in that the organic components of the waste would have to be treated before the mercury could be treated effectively. Treatment of this waste may be different from the other organic nonwastewaters, however, because recovery technologies may not be applicable for treatment of the nonwastewater residuals generated from incineration because reusable (i.e., nonradioactive) mercury may not be recoverable from these residuals. Radioactive hydraulic oils containing mercury thus represent a separate treatability group from other organic mercury nonwastewaters.

2.3.3 Wastewaters

EPA has determined that all mercury-containing wastewaters (K106, U151, P065, P092, and D009 wastewaters) represent a single treatability group. Treatment standards for K071 wastewaters were promulgated with the First Third of RCRA-listed hazardous wastes (53 FR 31137, August 17, 1988) and are not being proposed for revision. K106 wastewaters are generated from treatment of K106 wastes (e.g., as scrubber waters from thermal treatment methods). EPA has no data on the composition of K106, U151, or D009 wastewaters. However, the Agency expects K106 wastewaters to contain only the major constituents, which are mercury and non-BDAT list inorganics, reported for K106 wastes as generated (as shown in Table 2-4). EPA expects K106 and U151 wastewaters to contain suspended or dissolved metallic mercury or soluble inorganic mercury compounds (e.g., mercuric chloride). D009 wastewaters containing suspended or dissolved metallic mercury or soluble inorganic mercury compounds would also be included in this treatability group because dissolved or suspended inorganic D009 mercury compounds are expected to be amenable to treatment by the same technologies as are applicable for treatment of K071 and K106 wastewaters.

EPA has no data on P092 wastewaters, but expects these wastes to contain phenylmercuric acetate, a soluble organomercury compound, as a major constituent. As discussed in Section 2.1.3, EPA also expects D009 wastes generated from the paint formulation industry to contain phenylmercury compounds in an organic or inorganic waste matrix. Other D009 wastes, as generated, may be mixed with solvent constituents (USEPA 1986b). These wastewaters may require more extensive treatment trains (e.g., chemical oxidation with reagents such as hypochlorite or hydrogen peroxide) in order to treat organics that may interfere with the treatment of mercury. However, this currently lacks information that indicates that these wastes cannot be treated to similar levels as inorganic mercury wastewaters.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

In the previous section, discussions of the industries and processes generating mercury-containing wastes and major constituent analyses of these wastes were presented. Nine treatability groups were identified for the mercury-containing wastes. This section describes the applicable and demonstrated treatment technologies for treatment of these wastes. The technologies that are considered applicable to the treatment of mercury-containing wastes are technologies that treat BDAT list metals by reducing their concentration and/or their leachability in the waste and technologies that treat the organic compounds or organomercury compounds found in these wastes (so that the mercury content can subsequently be treated). Discussions of these treatment technologies can be found in EPA's Treatment Technology Background Document (USEPA 1989b).

3.1 Applicable Treatment Technologies

Based on the waste characteristics discussed in the previous section, the technologies applicable for treatment of mercury-containing wastes are those that reduce the concentration of BDAT list metals in the treated residual and/or reduce the leachability of these metals in the treated residual. Because organic mercury wastes (P065 wastes, P092 wastes, and some forms of D009 wastes) may contain organic mercury compounds or mercury compounds in an organic waste matrix), treatment technologies that are applicable to these wastes must also be able to free the mercury from its organic bond so that subsequent mercury treatment is effective.

3.1.1 Applicable Technologies for Nonwastewaters

The Agency has identified thermal mercury recovery processes, the acid leaching process, and stabilization as applicable for treatment of nonwastewaters containing metallic mercury and/or inorganic mercury

compounds. Incineration and chemical oxidation have been identified as applicable for treatment of nonwastewaters containing organomercury compounds or mercury in an organic waste matrix. Aqueous chemical deactivation and incineration in units specially designed for treatment of explosive wastes have been identified as applicable treatment technologies for treatment of reactive mercury-containing nonwastewaters. Absorption technologies have been identified as applicable for treatment of spilled metallic mercury wastes.

(1) Thermal mercury recovery processes. Thermal mercury recovery processes volatilize mercury from the waste at high temperatures and then condense and collect it as the pure metal, reducing the mercury concentration in the treatment residual compared to that in the untreated waste. Thermal recovery processes for mercury include retorting, roasting, distillation processes (vacuum distillation or batch steam distillation), and thermal processes recovering mercury from concentrated mercury ores.

Retorting and roasting processes can be cperated as batch processes in a closed vessel or continuously in a furnace. In retorting processes, waste is heated and mercury vaporizes and is collected in a condenser. The vessel is usually kept either at a slightly negative pressure or under a strong vacuum. Air is not introduced from outside the vessel. Roasting processes are usually operated continuously, but may be operated in batch. In roasting, air is supplied to the system as a source of oxygen to enable decomposition of some mercury compounds. Retorting and high-temperature metals recovery technologies are discussed further in the Treatment Technology Background Document (USEPA 1989b).

Distillation technologies are applicable to treatment of wastes containing high concentrations of metallic mercury (such as U151). The residuals from distillation technologies are a high-purity mercury as the "overhead" product and the remaining solid residual as the "bottoms." Distillation processes are also discussed in the Treatment Technology Background Document.

The thermal process recovering mercury from concentrated mercury ores is very similar to continuous retorting. This process is used by one facility in the U.S. in a continuous multiple-hearth furnace. All four thermal mercury recovery processes discussed above may generate a wastewater from air pollution control equipment that may contain mercury.

(2) Acid leaching process. Acid leaching solubilizes low concentrations of mercury in wastes, reducing the concentration of mercury in the nonwastewater treatment residual. The acid leaching process used for treatment of K071 wastes involves a chemical oxidation step followed by a step combining sludge dewatering and acid washing. This process generates an acid leachate (wastewater) that contains the mercury in soluble ionic form and requires treatment by chemical precipitation. Acid leaching is described in the Treatment Technology Background Document (USEPA 1989b).

(3) Stabilization. Stabilization is applicable for treatment of nonwastewaters containing BDAT list metals in an inorganic waste matrix. Stabilization treatment involves mixing the waste with a binding agent that is designed to reduce the leachability of metals from the waste. Common stabilization technologies are discussed in detail in the Treatment Technology Background Document (USEPA 1989b).

(4) Incineration. Incineration is applicable to treatment of wastes containing organic and organometallic constituents. Treatment using incineration technologies will destroy the organic constituents of the waste. As a consequence of destruction of the organics, incineration will break the organic-metal bond in the organometallic waste constituents. The metallic part of the organometallic constituents in the waste as well as any metals present in a mixed metal/organic waste will remain in the residual (ash) generated, be removed from the gases exiting the incinerator by the air pollution control equipment, or remain in the gases exiting the incineration system. Incineration technologies

are described in the Treatment Technology Background Document (USEPA 1989b). Technologies demonstrated for removal of mercury vapors, sulfur dioxide, and other gaseous air pollutants are discussed in Appendix B.

(5) Chemical oxidation of organomercury compounds. Chemical oxidation is applicable to the treatment of wastes containing organomercury constituents (such as phenylmercuric acetate, P092). Chemical oxidation treatment of organomercury compounds involves addition of a chemical oxidizing agent such as chlorine, hypochlorite, permanganate, or ozone in an aqueous reaction medium. Chemical oxidation results in the breaking of the organic-mercury chemical bond, thereby generating a residual from which the organic contaminant can either be destroyed (by further oxidation or incineration) or recovered (by distillation). Chemical oxidation is discussed in the Treatment Technology Background Document (USEPA 1989b). The inorganic mercury wastewaters resulting from chemical oxidation treatment can be treated by one of the technologies identified in Section 3.1.2 as applicable for wastewaters containing inorganic mercury compounds.

(6) Aqueous chemical deactivation. Aqueous chemical deactivation is applicable for treatment of wastes containing reactive mercury constituents (such as mercury fulminate, P065). Aqueous chemical deactivation involves careful dissolution of explosive solids in water, combined with oxidation treatment of the dissolved waste. In the case of mercury fulminate (mercuric cyanate), the dissolved cyanate ions can be chemically oxidized completely to carbon dioxide and nitrogen using strong aqueous oxidizing agents such as sodium hypochlorite. The chemical reaction of mercury fulminate with sodium thiosulfate ($Na_2S_2O_3$), recommended by the Army as the proper chemical deactivating agent (U.S. Army 1984), forms thiocyanate as follows:

$$Hg(OCN)_2 + 2Na_2S_2O_3 \rightarrow HgSO_4 + Na_2SO_4 + 2NaSCN$$

(7) Absorption of elemental mercury. Several methods have been developed to handle spills of liquid metallic mercury. These methods involve absorption of mercury with several agents. Calcium polysulfide and flowers of sulfur are the most common mercury absorbants used, and elemental zinc powder is also used.

Because of the high vapor pressure associated with elemental mercury in the liquid form, the predominant safety concern with elemental mercury wastes is air emissions. In absorption of liquid mercury with zinc dust, elemental zinc powder is applied to areas that have been contaminated with mercury. The visible droplets of liquid mercury are physically collected in a separate step before application of the zinc. The zinc is dampened with dilute sulfuric acid (5 to 10 percent) until a paste is formed. This paste is then collected for disposal. The mercury forms an amalgam with the zinc, providing a significant reduction in air emissions of mercury (Easton 1988). EPA prefers this procedure over the conventional spill cleanup procedures involving addition of calcium polysulfide or flowers of sulfur because use of zinc results in lower air emissions of mercury.

3.1.2 Applicable Technologies for Wastewaters

(1) Chemical precipitation and chemical reduction. EPA has identified chemical precipitation and chemical reduction, both followed by filtration, as applicable to treatment of mercury-containing wastewaters with high concentrations of inorganic mercury compounds. Chemical precipitation followed by filtration removes BDAT list metals and concentrates them in the wastewater treatment sludge. Chemical reduction (with reagents such as sodium borohydride) reduces mercury to the metallic state. The reduction step is then followed by filtration to remove mercury and other solids.

The applicability of chemical precipitation and chemical reduction technologies depends to some extent on the form of mercury in the waste (e.g., dissolved ionic, pure metal, and insoluble ionic). Mercury in the dissolved ionic form (soluble mercuric compounds, for example) may be reduced to the pure metal by the borohydride reduction process, while this process may not be effective in treatment of the insoluble mercury compounds. The borohydride process cannot remove the small amount of metallic mercury that is soluble in water. Chemical oxidation treatment may be required to oxidize metallic mercury to soluble ionic mercury prior to chemical precipitation treatment. Chemical precipitation, chemical reduction, and chemical oxidation technologies are discussed in the Treatment Technology Background Document (USEPA 1989b). The solids produced as a residual from chemical reduction processes are, in general, easier to treat by high-temperature metals recovery methods than are the solids produced in chemical precipitation treatment because they contain mercury in its elemental form rather than as mercuric sulfide.

(2) Chemical oxidation of organomercury constituents. EPA has identified chemical oxidation followed by chemical precipitation and filtration as an applicable technology for wastewaters containing organomercury constituents. Chemical oxidation breaks the bonds between the mercury and the organic components of these constituents, as discussed in Section 3.1.1(5). Chemical precipitation then treats the mercury in the inorganic form.

(3) Carbon adsorption and ion exchange. Two other technologies, carbon adsorption and ion exchange, are also applicable to treatment of wastewaters containing relatively low concentrations of dissolved mercury. The mercury must be in the soluble mercuric (Hg^{+2}) form in order to be removed by these technologies (Rosenzweig 1975, Iammartino 1975). Thus, these technologies may require pretreatment by chemical oxidation to solubilize any insoluble inorganic mercury. Carbon

adsorption will also remove mercury from wastes containing dissolved organomercury compounds.

Carbon adsorption and ion exchange produce both a wastewater residual (from regeneration of the ion exchange resin or activated carbon bed) and a nonwastewater residual (the spent carbon or ion exchange resin, when these are exhausted and must be discarded). The waste regenerant solutions (usually acid solutions) are more concentrated than the original waste treated and must usually be treated for mercury removal by chemical precipitation followed by filtration if these regenerant solutions are not recyclable to the process originally generating the waste. Spent carbon can be incinerated (if mercury emissions are controlled) or processed in a retort to recover residual mercury. The spent resins may also be processed by retorting to recover residual mercury. Carbon adsorption and ion exchange technologies are discussed in the Treatment Technology Background Document (USEPA 1989b).

3.2 Demonstrated Treatment Technologies

Section 3.1 described applicable technologies for treatment of mercury wastes. This section identifies, for nonwastewaters and wastewaters, those of the applicable technologies that are demonstrated in terms of the waste treatability groups that were discussed in Section 2.3. To be demonstrated, a technology must be in full-scale use to treat either the waste in question or a similar material.

3.2.1 Demonstrated Technologies for Nonwastewaters

Retorting, roasting, batch distillation technologies, and thermal treatment of mercury ores are all demonstrated for treatment of nonwastewaters containing mercury as the metal or as inorganic mercury compounds. Incineration has been identified as demonstrated for

treatment of nonwastewaters containing organomercury constituents or containing inorganic mercury in an organic waste matrix. Incineration in specially-designed units has been identified as demonstrated for explosive mercury nonwastewaters.

Retorting was used in the past to treat K106 at two mercury cell chlor-alkali facilities and to treat a mixture of K071 and K106 at another facility. EPA is not aware of any facilities currently retorting K106 sulfide wastes. However, a thermal treatment process similar to retorting is presently being used at one facility for recovery of mercury from ores consisting primarily of mercuric sulfide (cinnabar). These ores are concentrated to approximately 70 to 75 percent mercury prior to retorting (from 3 percent in the unprocessed ores). As shown in Table 2-4, the concentration of mercury in nonwastewater K106 generated by sulfide treatment averages 4.4 percent, and the concentration of mercury on K106 generated by hydrazine treatment is 0.5 percent. The processed mercury ores are much more concentrated in mercury (as mercury sulfide) than either form of K106. Hence, the Agency believes that the mercury ores are much more difficult to treat than K106. As a consequence, the Agency considers retorting to be demonstrated for K106 and other sulfide-containing nonwastewaters.

Retorting is also demonstrated at two additional facilities for treatment of nonsulfide-containing mercury nonwastewaters. U151 wastes and inorganic D009 wastes such as mercury lamps, debris, contaminated equipment, and mercury cell batteries are routinely treated by retorting, vacuum or scrap metal distillation, and a thermal proprietary process.

Incineration is demonstrated for many RCRA-listed hazardous wastes that contain BDAT list metals (such as K048-52 and K087). EPA believes incineration is currently used for treatment of organomercury wastes such as spent mercury catalysts from organic chemicals production, paint

sludges, or organomercury lab packs. Incineration in specially-designed units has been identified as a demonstrated technology for many D001 reactive wastes (USEPA 1989e), including some wastes that contain metals as well as organics. The U.S. Army recommends this technology for treatment of mercury fulminate (P065) wastes (U.S. Army 1984).

Absorption of mercury is a common method of cleanup of spilled mercury. Although not a conventional treatment technology, this technology is expected to provide some treatment for radioactive metallic mercury wastes, for which mercury recovery technologies may not be applicable.

Stabilization was identified as potentially applicable for treatment of K106 nonwastewaters. Stabilization typically binds BDAT list metals into a solid in a form that is more resistant to leaching than the metals in the untreated waste. EPA's testing of cement, kiln dust, and lime/fly ash stabilization for treatment of K106 nonwastewaters generated by sulfide precipitation indicates that the technology did not provide effective treatment. Based on this testing, EPA has concluded that these types of stabilization do not appear to be demonstrated for this form of K106. The stabilization data collected by EPA are summarized in Section 4. EPA recognizes, however, that the ineffectiveness of stabilization treatment of K106 in this EPA test may have resulted from the fact that the mercury present in the K106 waste tested was in a form that already had a low leachability for mercury. It is possible that stabilization may be applicable for treatment of other similar wastes if mercury is present in a more leachable form in untreated K106 or in other similar wastes. Other stabilizing agents, such as proprietary asphalt or silicate agents, may also be applicable but have not been tested for treatment of K106 or other mercury wastes.

3.2.2 Demonstrated Technologies for Wastewaters

Chemical precipitation followed by filtration has been demonstrated for treatment of K071 wastewater. EPA does not have characterization data on K106 wastewaters generated from retorting of K106. However, EPA does have data on wastewaters generated from air pollution control devices from the roasting of mercuric sulfide ores to recover metallic mercury. The Agency believes that these wastewaters (K106 wastewaters and wastewaters produced from mercuric sulfide ore processing) are similar to the K071 and other mercury-contaminated wastewaters currently treated by chemical precipitation (see Table 4-4) because they are expected to contain mercury as the major BDAT list constituent and are not expected to contain concentrations of organic compounds that would affect treatment by chemical precipitation. The concentration of mercury in the wastewaters for which the Agency has treatment data ranges from 23.7 to 77.2 mg/l. The ore roasting air pollution control wastewaters contained mercury up to 9.6 ppm (see Table 4-1). EPA would not expect the K106 wastewater generated from retorting to be more difficult to treat than the waste tested by the Agency because they are expected to have concentrations of mercury similar to that of the ore roasting air pollution control wastewaters generated in EPA testing of mercuric sulfide ore roasting. Chemical precipitation followed by filtration of mercury-containing wastewaters is used at 19 or more facilities.

Ion exchange is demonstrated at many facilities in Europe for treatment of wastewaters generated from the mercury cell chlor-alkali process. Activated carbon adsorption is also used at several facilities for treatment of inorganic mercury-containing wastewaters.

Therefore, the Agency believes that chemical precipitation, ion exchange, and carbon adsorption are all applicable and demonstrated for treatment of wastewaters generated from thermal treatment of K106

wastewaters and for the treatment of wastewaters generated from the management of other mercury-containing treatment sludge wastes.

Chemical oxidation is demonstrated for treatment of wastewaters containing mercury at concentrations up to 1,000 mg/l (as phenylmercuric acetate) at one facility that manufactures this compound. Therefore, this technology is demonstrated for treatment of organic and organometallic mercury wastewaters. Chemical oxidation technologies are also demonstrated for treatment of wastewaters containing oxidizable inorganic constituents (such as cyanide or cyanate) (USEPA 1989f).

As discussed in Section 3.2.1, incineration in specially-designed units is demonstrated for explosive mercury nonwastewaters. This technology is also recommended by the Army for treatment of mercury fulminate wastewaters, as well as aqueous chemical deactivation by chemical oxidation. Chemical oxidation is also demonstrated for many wastewaters containing organics or oxidizable inorganics (such as cyanate).

4. PERFORMANCE DATA

4.1 Performance Data for Nonwastewaters

For treatment of inorganic mercury-containing nonwastewaters, EPA has treatment performance data as described below. EPA collected 5 sets of treatment data from a thermal mercury recovery system that processes mercuric sulfide ores for mercury recovery. These data, presented in Table 4-1, show total composition, TCLP, and EP leachate data for both the untreated mercury ores and the treated nonwastewater furnace residue and also data for the wastewaters generated from the air pollution control devices. Also presented are design and operating data associated with each sample set.

Plant B submitted 4 sets of performance data for retorting treatment data of K106 hydrazine sludge, presented in Table 4-2. These data include total and EP leachate concentration of mercury in the untreated waste and data for mercury and the other EP metals in the treated nonwastewater residual, as well as design and operating data associated with each sample set.

Table 4-3 presents two sets of performance data on retorting treatment of a combined K071/K106 waste. These data show total mercury concentration for each test in the untreated waste and a range of total mercury concentrations for the treated nonwastewater residual, as well as design and operating data for each sample set.

Plant D submitted seven sets of performance data for retorting of a K106 sludge generated by sodium borohydride reduction and filtration. These data, presented in Table 4-4, show total mercury concentration of the untreated waste and total and EP leachate mercury concentrations for the treated nonwastewater residual. No design or oprating data were included.

Table 4-5 presents data collected by EPA on stabilization of K106 wastes. These data show the total and TCLP BDAT list metal concentrations for the untreated waste and the TCLP concentration for the treated waste. Three binding agents (lime/fly ash, kiln dust, and cement) were tested. The table presents the results of the test for kiln dust, which was the most successful of the three binding agents in terms of reduction of the TCLP leachate concentration for mercury. Both lime/fly ash and cement stabilization resulted in a significant increase in mercury TCLP leachate concentration in the treated waste compared to that in the untreated waste.

Data were presented in the BDAT background document for K071 (USEPA 1988b) on acid leaching treatment of K071 wastes. These data included both EPA-collected data and data submitted by industry.

4.2 Performance Data for Wastewaters

The Agency collected three data sets of untreated and treated data for treatment of K071 wastewater in a sulfide precipitation and filtration treatment system. The treatment performance data for K071 wastewaters are presented in Table 4-4.

EPA does not have analytical data on K106 wastewaters as generated from retorting operations. EPA believes that the K106 wastewaters generated would be similar in chemical and physical characteristics to wastewaters generated in treatment of K071 waste by acid leaching and other mercury-containing wastewaters.

The Agency does have data characterizing the wastewater generated from air pollution control at the facility at which mercuric sulfide ores were processed. These wastewaters contained up to 9.4 mg/l mercury and are similar in composition to K071 wastewaters.

Table 4-1 Ore Roasting Performance Data from Thermal Recovery of Mercuric Sulfide Ores Collected by EPA at Plant A.

Sample Set No. 1

Constituent	Untreated waste			Treated nonwastewater			Air pollution control wastewater
	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/l)
Antimony	330	0.82	-	1,170	0.47	-	3.23
Arsenic	290	0.41	0.33	960	7.3	4.54	0.023
Barium	13	0.69	0.19	77	0.21	0.14	0.007
Beryllium	0.15	<0.001	-	0.39	0.0013	-	<0.002
Cadmium	3.4	<0.005	0.007	5.0	0.051	0.037	<0.004
Chromium (total)	2.8	<0.003	0.009	5.2	<0.003	<0.003	<0.007
Copper	8.2	0.012	-	23	<0.003	-	<0.003
Lead	3.1	<0.05	<0.028	5.8	<0.005	<0.028	0.011
Mercury	625,000	0.26	0.10	45	<0.0002	<0.0002	3.25
Nickel	<1.0	<0.01	-	2.0	<0.01	-	<0.013
Selenium	3.6	<0.005	<0.005	<0.5	<0.05	<0.05	<0.005
Silver	2.8	<0.004	<0.004	7.6	<0.004	<0.004	<0.003
Thallium	6.2	0.03	-	<1.0	<0.01	-	0.013
Vanadium	5.4	<0.003	-	27	0.012	-	<0.003
Zinc	50	0.33	-	94	0.17	-	0.026

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1500-1530
Temperature of #4 furnace hearth (°F)	1450-1550	1580
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed

Reference: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 2

Constituent	Untreated waste			Treated nonwastewater			Air pollution control wastewater
	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/l)
Antimony	360	0.79	-	2,270	4.1	-	5.76
Arsenic	280	0.44	0.33	1,290	18.7	10.6	0.032
Barium	12	0.72	0.14	66	0.18	0.21	0.011
Beryllium	0.13	<0.001	-	0.43	<0.001	-	<0.002
Cadmium	2.7	0.006	<0.005	7.4	0.15	0.095	<0.004
Chromium (total)	3.1	0.004	<0.003	5.8	<0.003	<0.003	<0.007
Copper	8.4	0.013	-	26	<0.003	-	<0.003
Lead	3.2	<0.005	<0.028	10	<0.005	<0.028	0.017
Mercury	738,000	0.42	0.087	42.4	0.00047	<0.0002	8.52
Nickel	<1.0	<0.01	-	3.5	<0.01	-	<0.013
Selenium	2.8	<0.005	<0.005	<0.5	<0.05	<0.05	<0.005
Silver	2.6	<0.004	<0.004	8.6	<0.004	<0.004	<0.003
Thallium	5.6	0.03	-	<1.0	<0.01	-	0.029
Vanadium	5.1	<0.003	-	24	0.021	-	<0.003
Zinc	49	0.34	-	120	0.26	-	0.042

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1440-1510
Temperature of #4 furnace hearth (°F)	1450-1550	1540-1580
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed
Reference: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 3

Constituent	Untreated waste			Treated nonwastewater			Air pollution control wastewater
	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/l)
Antimony	320	0.82	-	1,920	0.94	-	2.73
Arsenic	270	0.44	0.36	1,220	12	1.1	0.029
Barium	12	1.03	0.13	70	0.18	0.13	0.010
Beryllium	0.12	<0.001	-	0.45	<0.001	-	<0.002
Cadmium	2.8	0.008	0.008	7.1	0.091	0.014	<0.004
Chromium (total)	3.5	0.006	<0.003	5.6	<0.003	<0.003	<0.007
Copper	9.0	0.014	-	32	<0.003	-	<0.003
Lead	3.0	<0.005	<0.028	7.0	<0.005	<0.028	0.013
Mercury	640,000	1.44	0.078	36	<0.0002	<0.0002	4.14
Nickel	1.2	<0.01	-	3.6	<0.01	-	<0.013
Selenium	5.5	<0.005	<0.005	<0.5	<0.05	<0.05	<0.005
Silver	3.5	<0.004	<0.004	10	<0.004	<0.004	<0.003
Thallium	5.1	0.031	-	<1.0	<0.01	-	0.027
Vanadium	5.2	<0.003	-	30	<0.003	-	<0.003
Zinc	52	0.64	-	140	0.073	-	0.032

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1480
Temperature of #4 furnace hearth (°F)	1450-1550	1570
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed
Reference: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 4

Constituent	Untreated waste			Treated nonwastewater			Air pollution control wastewater
	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/l)
Antimony	350	0.84	-	2,200	0.05	-	5.13
Arsenic	300	0.42	0.36	1,590	7.6	3.8	0.041
Barium	14	0.77	0.14	66	0.14	0.13	0.010
Beryllium	0.16	<0.001	-	0.43	0.00014	-	<0.002
Cadmium	3.3	0.006	<0.005	9.6	0.061	0.03	<0.004
Chromium (total)	3.7	0.006	<0.003	6.4	<0.003	<0.003	<0.007
Copper	9.0	0.010	-	28	<0.003	-	<0.003
Lead	3.3	0.006	<0.028	15	<0.005	<0.028	0.019
Mercury	473,000	3.8	0.093	23	<0.0002	<0.0002	7.26
Nickel	1.0	<0.01	-	4.6	<0.01	-	<0.013
Selenium	1.2	<0.005	<0.005	<0.5	<0.05	<0.05	0.012
Silver	3.2	<0.004	<0.004	9.6	<0.004	<0.004	<0.003
Thallium	5.1	0.037	-	<1.0	<0.01	-	0.041
Vanadium	5.8	<0.003	-	27	0.012	-	<0.003
Zinc	51	0.41	-	160	0.046	-	0.042

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1490
Temperature of #4 furnace hearth (°F)	1450-1550	1550-1560
Ore concentrate feed rate (lb/hr)	1000-1300	1310

- = Not analyzed

Reference: USEPA 1989g.

Table 4-1 (continued)

Sample Set No. 5

Constituent	Untreated waste			Treated nonwastewater			Air pollution control wastewater
	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/kg)	TCLP (mg/l)	EP leachate (mg/l)	Total (mg/l)
Antimony	340	0.90	-	2,310	15	-	4.64
Arsenic	300	0.41	0.36	1,250	18	4.7	0.037
Barium	14	0.76	0.14	71	0.16	0.12	0.012
Beryllium	0.15	<0.001	-	0.37	<0.001	-	<0.002
Cadmium	3.0	<0.005	<0.005	7.6	0.13	0.042	<0.004
Chromium (total)	3.1	0.005	<0.003	5.9	<0.003	-	<0.007
Copper	8.7	0.013	-	30.8	<0.003	-	<0.003
Lead	3.1	0.007	<0.028	7.4	<0.005	<0.028	0.018
Mercury	600,000	1.7	0.093	11	0.006	<0.0002	5.48
Nickel	1.3	<0.01	-	3.1	<0.01	-	<0.013
Selenium	2.3	<0.005	<0.005	<0.5	<0.025	<0.05	<0.005
Silver	3.2	<0.004	<0.004	9.5	<0.004	<0.004	<0.003
Thallium	5.1	0.026	-	<1.0	<0.01	-	0.043
Vanadium	5.6	<0.003	-	29	0.004	-	<0.003
Zinc	50	0.38	-	140	0.24	-	0.042

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Temperature of #2 furnace hearth (°F)	1350-1450	1490
Temperature of #4 furnace hearth (°F)	1450-1550	1560-1580
Ore concentrate feed rate (lb/hr)	1000-1300	1370

- = Not analyzed

Reference: USEPA 1989g.

Table 4-2 Treatment Performance Data for Retorting of K106 Hydrazine Sludge Submitted by Plant B

Sample Set No. 1

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	2.5	0.033
Barium	-	-	48	0.070
Cadmium	-	-	3.0	0.016
Chromium	-	-	38	<0.005
Lead	-	-	56	<0.06
Mercury	4,300	4.8	100	0.0017
Nickel	-	-	39	0.090
Selenium	-	-	<0.6	<0.005
Silver	-	-	6.5	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Reference: Occidental Chemical 1987.

Table 4-2 (continued)

Sample Set No. 2

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	2.7	0.030
Barium	-	-	44	0.11
Cadmium	-	-	2.8	0.013
Chromium	-	-	35	<0.005
Lead	-	-	99	<0.06
Mercury	5,500	5.3	90	0.0024
Nickel	-	-	35	0.11
Selenium	-	-	<0.6	<0.005
Silver	-	-	8.3	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Reference: Occidental Chemical 1987.

Table 4-2 (continued)

Sample Set No. 3

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	1.1	0.021
Barium	-	-	45	0.13
Cadmium	-	-	3.9	0.012
Chromium	-	-	68	<0.005
Lead	-	-	85	<0.06
Mercury	2,500	5.6	47	0.0005
Nickel	-	-	42	0.13
Selenium	-	-	<0.6	<0.005
Silver	-	-	9.9	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed
Reference: Occidental Chemical 1987.

Table 4-2 (continued)

Sample Set No. 4

Constituent	Untreated waste		Treated nonwastewater	
	Total (mg/kg)	EP leachate (mg/l)	Total (mg/kg)	EP leachate (mg/l)
Arsenic	-	-	1.0	0.021
Barium	-	-	40	0.14
Cadmium	-	-	4.6	0.015
Chromium	-	-	53	<0.005
Lead	-	-	71	<0.06
Mercury	2,000	5.8	41	<0.002
Nickel	-	-	33	0.12
Selenium	-	-	<0.6	<0.005
Silver	-	-	9.5	<0.007

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Retort temperature (°F)	1000	1000

- = Not analyzed

Reference: Occidental Chemical 1987.

Table 4-3 Treatment Performance Data for Retorting of Mixed K071/K106 Waste from Literature Source A

Constituent	Untreated waste Total concentration (ppm)	Treated waste Total concentration (ppm)
Sample Set No. 1		
Mercury	345	0.5 - 0.8
Sample Set No. 2		
Mercury	255	1.6 - 3.1
Sample Set No. 3		
Mercury	290	1.7 - 2.6
Sample Set No. 4		
Mercury	438	2 - 7.2
Sample Set No. 5		
Mercury	370	1.6

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value				
		SS#1	SS#2	SS#3	SS#4	SS#5
Waste feed rate (lb/hr)	300-700	540	560	580	450	680
Retort temperature (°F)	1200-1400	1400	1250	1350	1350	1386

Reference: Perry 1974.

Table 4-4 Treatment Performance Data for Retorting of K106 Sodium Borohydride Sludge Submitted by Plant C

Constituent	Untreated waste	Treated nonwastewater	
	Total (mg/kg)	Total (mg/kg)	EP Toxicity (mg/l)
Sample Set No. 1			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005
Sample Set No. 2			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005
Sample Set No. 3			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005
Sample Set No. 4			
Mercury	50,000[a]	0.5 - 10[b]	0.0082
Sample Set No. 5			
Mercury	50,000[a]	0.5 - 10[b]	0.0056
Sample Set No. 6			
Mercury	50,000[a]	0.5 - 10[b]	0.0036
Sample Set No. 7			
Mercury	50,000[a]	0.5 - 10[b]	<0.0005

[a]Only an approximate value was given for the untreated waste mercury concentration.

[b]Only one range was given for the treated waste total mercury concentration.

Reference: IMC 1982.

Table 4-5 Treatment Performance Data for Stabilization of K106
Collected by EPA at Plant D

Constituent	Untreated waste		Treated nonwastewater
	Total (ppm)	TCLP (mg/l)	TCLP (mg/l)
BDAT list metals			
Arsenic	1.1	<0.01	<0.004
Barium	74	0.74	0.326
Cadmium	2.3	0.02	<0.003
Chromium	6.3	<0.01	<0.02
Copper	133	<0.02	<0.003
Lead	50	0.13	<0.006
Mercury	25,900	0.01	0.0096
Nickel	14	0.15	<0.025
Silver	131	<0.02	0.007
Vanadium	0.46	<0.01	<0.007
Zinc	443	1.7	<0.013

Sample Set #2

Constituent	Untreated waste		Treated nonwastewater
	Total (ppm)	TCLP (mg/l)	TCLP (mg/l)
BDAT list metals			
Arsenic	1.1	<0.01	<0.004
Barium	74	0.74	0.362
Cadmium	2.3	0.02	0.004
Chromium	6.3	<0.01	<0.02
Copper	133	<0.02	<0.003
Lead	50	0.13	<0.0076
Mercury	25,900	0.01	0.023
Nickel	14	0.15	<0.025
Silver	131	<0.02	<0.006
Vanadium	0.46	<0.01	<0.007
Zinc	443	1.7	<0.013

Reference: USEPA 1988c.

Table 4-5 (continued)
Sample Set #3

Constituent	Untreated waste		Treated nonwastewater
	Total (ppm)	TCLP (mg/l)	TCLP (mg/l)
BOAT list metals			
Arsenic	1.1	<0.01	<0.004
Barium	74	0.74	0.355
Cadmium	2.3	0.02	<0.003
Chromium	6.3	<0.01	<0.02
Copper	133	<0.02	0.005
Lead	50	0.13	<0.006
Mercury	25,900	0.01	0.0093
Nickel	14	0.15	0.027
Silver	131	<0.02	<0.006
Vanadium	0.46	<0.01	<0.007
Zinc	443	1.7	<0.013

Reference: USEPA 1988c.

Table 4-6 Performance Data for Sulfide Precipitation Treatment of K071 Wastewaters Collected by EPA at Plant E

ANALYTICAL DATA:

BOAT list constituent	Sample Set #1 Untreated wastewater (mg/l)	Sample Set #1 Treated wastewater (mg/l)	Sample Set #2 Untreated wastewater (mg/l)	Sample Set #2 Treated wastewater (mg/l)	Sample Set #3 Untreated wastewater (mg/l)	Sample Set #3 Treated wastewater (mg/l)	Filter cake (K106)[a] Total (mg/kg)	Filter cake (K106)[a] TCLP (mg/l)
Arsenic	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1	1.1	<0.01
Barium	0.248	0.103	0.226	0.158	0.293	0.144	74	0.74
Cadmium	<0.03	<0.06	<0.06	<0.06	<0.06	<0.06	2.3	0.02
Chromium	<0.06	0.553	0.189	<0.12	<0.12	<0.12	6.3	<0.01
Copper	0.097	<0.16	<0.16	<0.16	<0.16	<0.16	133	<0.02
Lead	<0.66	<1.32	<1.32	<1.32	<1.32	<1.32	50	0.13
Mercury	23.7	0.028	9.25	0.027	77.2	0.028	25,900	0.01
Nickel	0.157	0.275	<0.26	<0.26	<0.26	<0.26	14	0.15
Silver	0.148	<0.1	0.1	<0.1	0.12	<0.1	131	<0.02
Vanadium	<0.04	<0.08	<0.08	<0.08	<0.08	<0.08	0.46	<0.01
Zinc	0.615	0.047	0.88	<0.04	0.535	0.064	443	1.7

DESIGN AND OPERATING PARAMETERS:

Parameter	Design value	Operating values Sample Set #1	Sample Set #2	Sample Set #3
Excess sulfide	>40 mg/l	85 mg/l	101 mg/l	96 mg/l

[a]Only one sample was collected of the filter cake (K106).

Reference: USEPA 1988b.

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the rationale for the determination of best demonstrated available technology (BDAT) for mercury-containing nonwastewaters and wastewaters. To determine BDAT, the Agency examines all available performance data for the technologies that are identified as demonstrated for each treatability group to determine whether one of these technologies performs significantly better than the others. All performance data used for determination of best technology must first be adjusted for accuracy, as discussed in EPA's publication Methodology for Developing BDAT Treatment Standards (USEPA 1989a).* BDAT must be specifically defined for all streams associated with the management of the listed waste or wastes; this includes the original waste as well as any residual waste streams created by the treatment process.

The technology that performs best on a particular waste or waste subcategory is then evaluated to determine whether it is "available." To be available, the technology must (1) be commercially available to any generator and (2) provide "substantial" treatment of the waste, as determined through evaluation of accuracy-adjusted data. In determining whether a technology is available, EPA may consider data on the performance of a waste similar to the waste in question, provided that the similar waste is at least as difficult to treat.

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*Accuracy adjustment accounts for the ability of an analytical technique to recover a particular constituent from the waste in a particular test. The recovery of a constituent is determined by spiking a sample with a known amount of the target constituent and then comparing the result of analysis of the spiked sample with the result from the unspiked sample.

5.1 BDAT for Nonwastewaters

EPA reviewed the available treatment performance data for mercury-containing wastes presented in Section 4 to determine whether they represent the operation of well-designed and well-operated systems and whether sufficient quality assurance/quality control (QA/QC) data were collected to assess the accuracy of the treated waste analyses. Identification of BDAT for nonwastewaters is discussed below for each treatability group.

5.1.1 Inorganic Mercury Nonwastewaters - High-Mercury Subcategory

EPA has identified several thermal mercury recovery technologies, including retorting, roasting, batch vacuum or steam distillation, and a proprietary process as demonstrated technologies for inorganic mercury nonwastewaters in the high-mercury subcategory. The Agency has also identified thermal processing of mercuric sulfide (cinnabar) ores as a technology that is used to recover mercury from wastes more difficult to treat than most inorganic mercury wastes because of the higher mercury content in these ores than in mercuric sulfide-containing wastes for which EPA has waste composition data (see Section 3.2.1).

For treatment of wastes in which mercury is present as metallic mercury or as inorganic mercury compounds, the Agency has data from four tests as follows:

- Five sets of performance data (presented in Table 4-1) from recovery of mercury from cinnabar ores by a thermal treatment process that is very similar to retorting waste treatment processes.
- Four sets of performance data from retorting of K106 generated by hydrazine treatment of mercury-containing wastewaters (presented in Table 4-2),

- Five sets of performance data from retorting of a mixed K071/K106 waste (presented in Table 4-3) which contained 95 percent K071 and 5 percent K106 sulfide sludge, and

- Seven sets of performance data from retorting of K106 generated by borohydride reduction treatment (presented in Table 4-4).

The treatment data presented in Table 4-1 include total composition TCLP leachate, and EP leachate data for both the untreated waste and the treated nonwastewater residual as well as total composition data for the air pollution control wastewaters (primarily SO_2 scrubber waters). QA/QC information was also provided. The data presented in Table 4-2 include total and EP Toxicity procedure leachate concentrations for mercury and the other EP metals for the treated nonwastewater as well as design and operating information. QA/QC information (analytical recoveries) was also provided with these data. The data in Table 4-3 include a range of total mercury concentrations in the treated nonwastewater for each test, as well as design and operating data. EPA considered the highest value of the range in each test as the value that represented treatment performance for that test. No analytical QA/QC data were provided. However, from the detail of the analytical method provided in the report, EPA believes that the data were adjusted for analytical recovery before presentation in the report. The data in Table 4-3 present the EP leachate mercury concentration for each sample set for the treated nonwastewater but only a range of total mercury concentrations for the seven sample sets. No QA/QC data were provided.

The data in Table 4-4 were not used in determination of "best" performance because only a range (i.e., two data points) was given, and no operating or QA/QC data were given for the test. However, this data set indicates that similar performance was achieved in retorting of the K106 borohydride sludge as was achieved in retorting of the mixed K071/K106 sludge.

The treatment performance data presented in Table 4-1 were adjusted for analytical recovery to take into account analytical interferences associated with the chemical makeup of the treated waste samples. In the QA/QC test for analytical recovery, EPA first analyzes a waste for a constituent and then adds a known amount (i.e., a spike) of the same constituent to the waste material and reanalyzes the sample for that constituent. The difference between the total amount detected after spiking and the concentration detected in the unspiked sample divided by the amount of spike added is the recovery value. (If recovery tests are run in duplicate, EPA uses the lower recovery value.) The reciprocal of the recovery multiplied by the analytical value obtained during performance testing is the accuracy-corrected value used in comparing treatment effectiveness and subsequently in calculating treatment standards. Percent recovery values for constituents detected in the mercury ores tested are presented in Appendix A. The accuracy-adjustment of performance data for total mercury for thermal processing of mercury ores is detailed in Table 5-1.

EPA also adjusted the data presented in Table 4-2 for accuracy. These calculations are summarized in Table 5-1, along with the treatment data from Table 4-3. The three data sets for total mercury concentration summarized in Table 5-1 were compared using EPA's analysis of variance (ANOVA) procedure. The ANOVA is described in the methodology document (USEPA 1989a). A comparison of the accuracy-adjusted treatment data presented in Table 5-1 for total mercury composition indicates that the retorting performance data for treatment of the mixed K071/K106 sludge represents better treatment than the data from retorting of the K106 hydrazine sludge and from thermal recovery of mercury from cinnabar ores.

The design and operating data provided in Table 4-1 show that the thermal ore processing system was well operated during the test. Even though the total composition mercury data from this test show higher

mercury concentrations in the residual from thermal ore processing than for the K071/K106 retorting test, the EP Toxicity procedure and TCLP leachates from the ore processing residuals show that mercury leaches from these residuals at very low levels. The range of TCLP leachate concentrations for mercury in these residuals, reported in Table 4-1, is 0.0002 to 0.006 mg/l (ppm). The EPA leachate concentrations reported for mercury in the same table are all below 0.0002 mg/l (ppm).

The design and operating data presented in Table 4-2 for the K106 hydrazine sludge indicate that this retorting test was performed at a much lower temperature (1000°F versus 1250-1400°F) than was the test of the mixed K071/K106 wastes. This could account for the poorer treatment performance in this test.

Based on the data presented for thermal treatment of mercury wastes in Table 5-1, retorting for recovery of mercury has been determined to be the best technology for treatment of inorganic mercury nonwastewaters. All of the treatment data for thermal mercury recovery processes presented in Section 4 show that substantial treatment is achieved based on the reduction in total, TCLP, and EP leachate mercury concentrations in the treated nonwastewater compared to that in the untreated waste. The thermal ore processing technology is used at the one U.S. mine that is known to process mercury ores. Similar technologies (retorting and roasting) are used or have been used at several chlor-alkali facilities in the U.S. and in Europe to process mercury wastewater treatment sludges. Therefore, thermal recovery of mercury is available and thus has been determined to be BDAT for inorganic mercury nonwastewaters.

5.1.2 Inorganic Mercury Nonwastewaters - Low-Mercury Subcategory

EPA has identified acid leaching as the only demonstrated treatment technology for inorganic mercury nonwastewaters with total mercury

concentrations too low to be amenable to recovery by thermal recovery technologies (i.e., the low-mercury subcategory). Evaluation of these data for proper system design and operation and calculation of accuracy-adjusted treatment data are included in the BDAT background document for K071 (USEPA 1988b).

5.1.3 Organic Mercury Nonwastewaters

EPA has identified incineration as the only demonstrated technology for treatment of mercury-containing nonwastewaters that contain organomercury constituents (such as phenylmercuric acetate) or that contain mercury in an organic waste matrix. No data are available to the Agency on incineration of organic mercury nonwastewaters. However, incineration data for a mixed K048/K051 waste that contained an organolead compound (tetraethyl lead) in an organic waste matrix showed that organics were destroyed in the resulting incinerator ash and scrubber waters and the lead was concentrated in these two residual waste matrices. EPA expects the same to happen for incineration of organic mercury nonwastewaters. Therefore, incineration has been determined to be BDAT for P065, P092, and D009 organic mercury nonwastewaters followed by treatment of the ash and scrubber water residuals by the BDAT specified for inorganic high-mercury nonwastewaters and mercury-containing wastewaters in Sections 5.1.1 and 5.2, respectively.

5.1.4 Nonwastewaters Containing Radioactive Materials

In Section 2.3.4, EPA discussed two subcategories of nonwastewaters containing reactive materials that have been reported to be generated by DOE. These were described as metallic mercury-containing radioactive materials and waste hydraulic oil contaminated with metallic mercury and radioactive materials.

The Agency has no data or information to indicate that thermal mercury recovery processes that are demonstrated for treatment of inorganic high-mercury nonwastewaters would be able to separate the mercury from the radioactive material (tritium) that is the contaminant in the metallic mercury waste generated by DOE. Thus, the Agency believes that technologies demonstrated for these wastes are the absorption technologies discussed in Section 3.1.1(7). Common absorbants used are zinc dust, calcium disulfide, and flowers of sulfur. EPA prefers amalgamation with zinc over conventional spill cleanup procedures involving addition of calcium polysulfide or flowers of sulfur because use of zinc results in lower air emissions of mercury.

The Agency currently has no information on whether this procedure will reduce the overall leachability of mercury. However, the Agency has determined that this procedure does provide significant treatment due to the decrease in air emissions, the change in mobility from liquid mercury to a paste-like solid, and the potential reduction in leachability due to the amalgamation with the zinc. Based on this information, the general lack of treatment data, the lack of alternative technologies, and the unique handling problems associated with the radioactivity, the Agency has determined that amalamation with zinc represents the best technology for treatment of elemental mercury wastes contaminated with radioactive materials.

EPA feels that incineration, which is demonstrated for treatment of nonradioactive organic mercury nonwastewaters, is also demonstrated for treatment of waste hydraulic oil contaminated with mercury and radioactive materials (tritium). However, EPA does not expect recovery technologies to be applicable to the treatment of nonwastewater residuals generated from incineration treatment of this waste. Therefore, the best technology for treatment of the inroganic low-mercury nonwastewaters, acid leaching, is also BDAT for treatment of the nonwastewater residuals generated from incineration of this waste.

5.2 BDAT for Wastewaters

EPA has identified chemical precipitation followed by filtration, carbon adsorption, and ion exchange as demonstrated technologies for treatment of mercury-containing wastewaters where the mercury constituent is inorganic. EPA has identified chemical oxidation followed by chemical precipitation and filtration, incineration, ion exchange, and carbon adsorption as demonstrated technologies for the treatment of wastewaters containing organomercury constituents or inorganic mercury in an organic waste matrix.

As discussed in Section 4, EPA does not have treatment data for wastewaters generated from retorting. However, EPA does have chemical precipitation treatment data for K071 mercury-containing wastewaters, presented in Table 4-6. The Agency has determined that these wastewaters are at least as difficult to treat as wastewaters generated from retorting because the concentrations of mercury and other metals are similar and neither waste contains significant concentrations of any interfering substances. These wastewaters are also expected to be at least as difficult to treat as other mercury-containing wastewaters that would be classified as D009 wastes because of the relatively high concentration of mercury in the K071 wastewaters and because the Agency has no data indicating that D009 wastewaters are routinely generated containing significant concentrations of constituents (such as oil and grease) that would affect performance of chemical precipitation treatment. This technology substantially reduces the concentration of mercury in wastewaters, as noted in Table 4-6, where untreated mercury concentrations of as much as 77 mg/l are treated to 0.028 mg/l.

EPA has no data on the demonstrated adsorption technologies (ion exchange and carbon adsorption). However, when these technologies are used, a regenerant solution is produced that is either recycled or must

be treated by chemical precipitation. Therefore, the chemical precipitation treatment standard would ultimately apply to wastewaters generated by these technologies.

Data collected by the Agency on treatment of K071 wastewater by sulfide precipitation and filtration are shown in Table 4-6. Operating data collected during treatment of this waste show that these data represent the performance of a well-designed, well-operated treatment system. EPA adjusted the data values based on the analytical recovery values in order to take into account analytical interferences associated with the chemical makeup of the treated sample. Accuracy adjustment of mercury concentrations for these treatment data is detailed in Table 5-2. The analytical recovery values used in these calculations are presented Appendix A.

EPA's determination of substantial treatment is based on the observed reduction in total mercury concentration from 77.2 ppm to 0.028 ppm in the K071 mercury-containing wastewaters considered by EPA to be similar to other inorganic mercury-containing wastewaters.

The Agency believes that this reduction in the concentration of hazardous constituents is substantial and that sulfide precipitation followed by filtration is available to treat these wastes because it is a common commercially available wastewater treatment technology. Therefore, sulfide precipitation followed by filtration represents BDAT for these wastewaters.

The Agency does not have data on the effectiveness of chemical oxidation treatment of wastewaters contaminated with organics or organomercury compounds followed by chemical precipitation and filtration to enable it to compare this treatment to the performance of sulfide precipitation treatment of inorganic mercury wastewaters. Lacking these data, EPA has determined that chemical precipitation is also the best

technology for the treatment of organic mercury wastewaters. Incineration may be required as a pretreatment method for organometallic wastes to destroy the organics and concentrate the metals in the residual ash or the incineration scrubber waters. Resulting scrubber waters would be expected to be free of organics; therefore, mercury in these wastewaters is then expected to be able to be treated by chemical precipitation with similar effectiveness as treatment of inorganic mercury wastewaters. Chemical oxidation may also be effective as a pretreatment method for organics prior to chemical precipitation.

EPA has no data on the demonstrated adsorption technologies (ion exchange and carbon adsorption), but these technologies ultimately generate a residual (the spent carbon or ion exchange resin) that must be thermally processed (incinerated or retorted) to recover mercury. (In the cases where the mercury is adsorbed as an organomercury compound, incineration may be the only thermal treatment option.) Therefore, either retorting/roasting or incineration are ultimately the best technologies for treatment of nonwastewater residuals generated by these treatment technologies, and the incineration treatment standard also applies to nonwastewater residuals generated from the use of these technologies to treat organic mercury wastewaters.

No data are available on the treatment of P065 wastewaters or D009 reactive mercury wastewaters by the demonstrated technologies (aqueous chemical deactivation and incineration) identified in Section 3.2.2. However, based on the demonstrated effectiveness of incineration of other explosive and reactive D001 wastes (USEPA 1989e), the Agency has determined that BDAT for the explosive mercury nonwastewaters (incineration in specially-designed units) followed by treatment of scrubber waters produced from incineration by the BDAT for inorganic mercury wastewaters (chemical precipitation followed by filtration) is BDAT for explosive mercury wastewaters (P065 and explosive D009

wastewaters). The determination is based on the same reasons as were discussed in Section 5.1.4 for explosive mercury nonwastewaters and in Section 5.2.1 for inorganic mercury wastewaters.

Table 5-1 Summary of Accuracy Adjustment of Treatment Data for Total Mercury Generated from Thermal Recovery Technologies

	Untreated waste concentration (mg/kg)	Measured treated waste concentration (mg/kg)	Percent recovery for treated waste matrix	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Thermal Treatment of Mercuric Sulfide Ores					
Sample Set No. 1	625,000	45	113	1.0	45
Sample Set No. 2	738,000	42.4	113	1.0	42.4
Sample Set No. 3	640,000	36	113	1.0	36
Sample Set No. 4	473,000	23	113	1.0	23
Sample Set No. 5	600,000	11	113	1.0	11
Retorting of K106 Hydrazine Sludge					
Sample Set No. 1	4,300	100	89	1.12	112
Sample Set No. 2	5,500	90	89	1.12	101
Sample Set No. 3	2,500	47	89	1.12	53
Sample Set No. 4	2,000	41	89	1.12	46
Retorting of Mixed K071/K106					
Sample Set No. 1	345	NA	NA	NA	0.8
Sample Set No. 2	255	NA	NA	NA	3.1
Sample Set No. 3	290	NA	NA	NA	2.6
Sample Set No. 4	438	NA	NA	NA	7.2
Sample Set No. 5	370	NA	NA	NA	1.6

NA = Not available. Data from Literature Source A (Perry 1974), as presented in Table 4-3, are assumed to have been corrected for accuracy of the analytical method.

Table 5-2 Summary of Accuracy Adjustment of Treatment Data for Total Mercury in Wastewaters

	Untreated waste concentration (mg/l)	Measured treated waste concentration (mg/l)	Percent recovery for treated waste matrix	Accuracy correction factor	Accuracy-adjusted concentration (mg/l)
Chemical Precipitation					
Sample Set No. 1	23.7	0.028	95	1.05	0.0295
Sample Set No. 2	9.25	0.027	95	1.05	0.0284
Sample Set No. 3	77.2	0.028	95	1.05	0.0295

6. SELECTION OF REGULATED CONSTITUENTS

In Section 5, the best demonstrated available technology (BDAT) was determined for each waste treatability group for the mercury-containing wastes K071, K106, U151, P065, P092, and D009. This section describes the selection of constituents to be regulated for each waste code. The selected constituents must be present in the untreated waste at concentrations that are treatable by the chosen BDAT discussed in Section 5.

6.1 Nonwastewaters

In the EPA treatment test of thermal processing of mercuric sulfide ores, the Agency analyzed the untreated ore samples for BDAT list metals and BDAT list organic compounds, as well as for total organic carbon (TOC). No treatable concentrations of organic compounds were detected in these samples. Thus, these ores are similar to the K106 mercuric sulfide sludge wastes as generated (see Table 2-4).

The mercuric sulfide ores sampled by EPA were not analyzed for certain compounds on the BDAT list (specifically organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorus insecticides, PCBs, and dioxins and furans) because the Agency is not aware of any in-process source of these constituents and would therefore not expect any of these constituents to be present at treatable concentrations. Two inorganics other than metals on the BDAT list (fluoride and cyanide) were not analyzed. Even though these constituents were not analyzed, EPA would not expect fluoride or cyanide to be present at treatable concentrations in the wastes tested.

The K106 hydrazine sludge treated at Plant B was analyzed only for the eight EP characteristic metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). None of the metals other than mercury were detected at treatable concentrations in this K106 waste.

Results of retorting treatment of the mixed K071/K106 sludge reported in Literature Source A (see Table 4-3) prsented only total mercury concentrations. However, no treatable concentrations of other BDAT list constituents were expected to be detected for this waste. Results of retorting of K106 at Plant C (presented in Table 4-4) also only reported mercury concentrations. No other BDAT list constituents were expected to be present at treatable concentrations in this waste.

Upon analysis of data on characaterization and treatment of K071 and K106 wastes generated in the mercury cell chlor-alkali process and available information about this process, EPA concludes that mercury is the only BDAT list constituent expected to be routinely present in wastes from this process. Thus, the Agency has determined that mercury is the only regulated constituent for K106 and for the reproposal of treatment standards for K071 nonwastewaters. Mercury was previously selected (in the First Third regulations) as the only regulated constituent for K071 nonwastewaters and wastewaters (USEPA 1988b).

For P065, P092, and U151, mercury is expected to be the only BDAT list metal constituent of the waste (unless the wastes are mixed with other listed or characteristic hazardous wastes, in which case other treatment standards would also apply). P092 is also expected to contain organic constituents (benzene, in particular). Mercury has been selected as the only regulated constituent for these U- and P-code mercury-containing wastes. No data are available to EPA on the treatment of organics in P092 wastes. However, the Agency expects the organic constituents of P092 to be destroyed by incineration of P092 wastes, which is required as a method of treatment. EPA also expects that the fulminate constituent of P065 (mercury fulminate) and the reactive constituents of D009 reactive wastes will be destroyed by incineration, which is required as a method of treatment for organic mercury wastes. Incineration also removes the reactivity characteristic associated with these wastes.

Mercury has also been selected as the only constituent for regulation for D009 wastes. EPA does not have sufficient characterization data for D009 wastes to determine whether these wastes commonly contain other BDAT list constituents at treatable concentrations. If these wastes contain organic constituents, EPA believes that these constituents will be destroyed by incineration, which is a required method of treatment for organic D009 nonwastewaters.

6.2 Wastewaters

EPA does not have data on the composition or treatment of K106 wastewaters generated from retorting. However, EPA does have data that indicate that mercury is the only BDAT constituent present in wastewaters generated from recovery of mercury from mercuric sulfide ores in a multiple-hearth furnace (see Table 4-1). Thus, EPA would not expect any BDAT constituent other than mercury to be present in treatable quantities in the K106 wastewater for reasons already presented in the discussion of nonwastewaters. Mercury has therefore been selected as the only regulated constituent for K106 wastewaters.

Mercury has been selected as the only regulated constituent in P065, P092, U151, and D009 wastewaters. Mercury is the only constituent for which these wastes are listed and is the only BDAT list constituent expected to be present in these wastes, with the following exceptions:

- If these wastes are mixed with other listed or characteristic hazardous wastes, other appropriate treatment standards would also apply.
- For P092 and organic D009 wastes, organic constituents will be present; incineration is required as a method of treatment for these organics.
- For P065 (which may be reactive) and reactive D009 wastes, incineration is required as a method of treatment for the reactivity characteristic of these wastes.

7. CALCULATION OF TREATMENT STANDARDS

This section presents the calculation of the proposed numerical treatment standards for K071, K106, P065, P092, U151, and D009 wastes using the treatment data presented for the best demonstrated available technologies, as determined in Section 5. In Section 6, mercury was selected as the only regulated constituent for both nonwastewater and wastewater forms of the wastes.

The Agency bases treatment standards for regulated constituents on the performance of well-designed and well-operated BDAT treatment systems. These standards must account for analytical limitations in available performance data and must be adjusted for variabilities related to treatment, sampling, and analytical techniques and procedures.

BDAT standards are determined for each constituent by multiplying the arithmetic mean of accuracy-adjusted constituent concentrations detected in treated waste by a "variability factor" specific to each constituent for each treatment technology defined as BDAT. Accuracy adjustment of performance data has been discussed in Section 5 in relation to defining BDAT. Variability factors account for normal variations in the performance of a particular technology over time. They are designed to reflect the 99th percentile level of performance that the technology achieves in commercial operation. (For more information on the principles of calculating variability factors, see EPA's publication Methodology for Developing BDAT Treatment Standards (USEPA 1989a).) Details on the calculation of variability factors for mercury-containing nonwastewaters and wastewaters are presented in this section.

Where EPA has identified BDAT for a particular waste, but because of data limitations or for some other compelling reason cannot define specific numerical treatment standards for that waste, the Agency can

require the use of that treatment process as a technology standard. The rationale for specifying technology standards for certain mercury wastes or waste groups, either in lieu of or in addition to numerical treatment standards, is also discussed in this section.

7.1 Wastewaters

EPA collected three sets of untreated and treated K071 wastewater data from one facility using sulfide precipitation followed by filtration. The following steps were taken to derive the numerical BDAT treatment standards for wastewaters:

- Accuracy-corrected constituent concentations were calculated for mercury. These calculations are presented in Table 5-2.
- The Agency evaluated the data collected from the sulfide precipitation treatment system to determine whether any of the data represented poor design or poor operation. The available design and operating data show that all three data sets collected from the Agency testing for wastewater represent the performance of a well-designed, well-operated system.
- An arithmetic average concentration level and a variability factor were determined for the BDAT list constituent (i.e., mercury) regulated in this waste.
- The BDAT treatment standard for mercury was determined by multiplying the average accuracy-corrected total concentration by the variability factor, which has been calculated to be 1.05.

Table 7-1 summarizes the calculation of the numerical treatment standards for mercury-containing wastewaters. It was determined in Section 5 that incineration may be necessary as a pretreatment step for organic or reactive mercury wastewaters. However, no treatment data are available for treatment of wastewaters containing organomercury constituents or mercury and organic constituents. EPA is thus not requiring the use of incineration as a treatment technology standard for organic mercury wastewaters. EPA expects the incineration scrubber water residual generated from treatment of organomercury wastewaters to be free

of organics and thus no more difficult to treat than inorganic mercury wastewaters. Table 7-4 presents proposed BDAT treatment standards for all mercury-containing wastewaters.

7.2 Nonwastewaters

In Section 5, the retorting performance data of a mixed K071/K106 waste were determined to represent the performance of the BDAT for inorganic mercury nonwastewaters containing high concentrations of mercury (the high-mercury subcategory). Acid leaching was determined to be BDAT for inorganic mercury nonwastewaters in the low-mercury subcategory. The retorting performance data from K071/K106 were used to determine a level of mercury that would classify a waste as either a high-mercury waste or a low-mercury waste. The following steps were taken to derive the total mercury concentration used to distinguish between subcategories for inorganic mercury nonwastewaters.

- Accuracy-corrected constituent concentrations for these data were presented in the original report of treatment system performance. The accuracy-adjusted data are presented in Table 5-1.

- The Agency evaluated the data collected from the retorting treatment system to determine whether any of the data represent poor design or poor operation. The available design and operating data indicate that all five sets of data represent the performance of a well-designed, well-operated system.

- An arithmetic average concentration level and a variability factor were determined for the BDAT list constituent (i.e., mercury) regulated in this waste.

- The 16 mg/kg cutoff level was determined by multiplying the average accuracy-corrected total mercury concentration by the variability factor.

This 16 mg/kg level represents the anticipated performance of retorting or roasting treatment of mercury wastes based on the best data

available to the Agency. Data from the thermal processing of cinnabar ores were analyzed in the same way as the K071/K106 performance data to determine the performance level that could be expected from roasting/retorting of these ores (see Table 7-2). These calculations suggest that mercury sulfide-containing wastes with untreated mercury concentrations as high as those in the ores (over 50 percent by weight) would yield higher mercury concentrations (over 100 mg/kg) when roasted or retorted. However, an analysis of the performance data from the thermal processing of cinnabar ores suggests that none of the residues resulting from the retorting or roasting of mercury sulfide-containing wastes are likely to leach mercury at greater than 0.2 mg/l when tested by either the TCLP or the EP Toxicity procedures. The processed cinnabar ores that were roasted/retorted had well over 50 percent mercury. EPA believes that this concentration is much higher than in typical mercury wastes and that the K071/K106 wastes that were roasted/retorted are more representative. Hence, EPA is proposing that 16 mg/kg total mercury concentration level, based on the treatment of the K071/K106 wastes, to identify those mercury-containing wastes amenable to mercury recovery by retorting or roasting.

For the purpose of this rule, K071, K106, U151, and D009 wastes containing greater than or equal to 16 mg/kg total mercury are classified as high-mercury subcategory wastes. Similarly, K071, K106, U151, and D009 wastes containing less than 16 mg/kg total mercury are classified as low-mercury subcategory wastes.

Table 7-3 summarizes the calculation of the 16 mg/kg cutoff level between high-mercury wastes and low-mercury wastes for inorganic mercury nonwastewaters.

The inorganic mercury nonwastewaters in the high-mercury subcategory waste must be processed for mercury recovery using a thermal recovery technology. This is required as a technology treatment standard. The

residual nonwastewater from recovery is considered indigenous to the process; therefore, the derived-from rule does not apply to this residual. However, this residual must still be further treated by a thermal mercury recovery technology if it is EP toxic for mercury and is classified as a D009 high-mercury subcategory waste (i.e., greater than 16 mg/kg total mercury concentration).

Incineration was selected in Section 5 as BDAT for organic mercury nonwastewaters (P065, P092, and organic D009 wastes). However, no incineration performance data are available for treatment of these wastes or wastes containing similar concentrations of mercury and organic constituents. Therefore, EPA is requiring the use of incineration as a treatment technology for these wastes. The Agency is also proposing technology-based treatment standards for treatment of nonwastewater incineration residuals (incinerator ash and wastewater treatment sludges generated from treatment of scrubber waters). EPA believes that the incineration residuals generated from treatment of the organomercury wastes will be free of organics and thus no more difficult to treat than inorganic mercury nonwastewaters and wastewaters.

Tables 7-5 through 7-8 present treatment standards for K071, K016, U151, P065, P042, and D009 nonwastewaters.

In Section 5, amalgamation with zinc was selected as BDAT for the radioactive elemental mercury wastes. No performance data are available on this treatment process. Therefore, EPA has established amalgamation with zinc, as described in Section 3.1.1(7), as a technology-based treatment standard for these wastes. The treatment standard is shown in Table 7-9.

Incineration was determined to be BDAT for hydraulic waste oils contaminated with mercury and radioactive materials. EPA has no data on the performance of incineration for treatment of these wastes, but

expects incineration to destroy the organic content of the waste. EPA has therefore established standards based on treatment of the residuals generated from incineration treatment of these wastes. EPA expects these incineration residuals (incineration ash and scrubber waters) to be no more difficult to treat than low-mercury nonwastewaters and K071 mercury-containing wastewaters, respectively. The Agency is therefore transferring performance of acid leaching treatment for K071 nonwaste- waters to the treatment of the incinerator ash residues from incineration of this waste and transferring the performance of chemical precipitation of K071 wastewaters to the treatment of scrubber waters generated from incineration. The proposed treatment standard for hydraulic oils contaminated with mercury and radioactive materials is shown in Table 7-10.

Table 7-1 Calculation of Numerical Treatment Standards for Wastewaters

Constituent	Accuracy-adjusted treated waste concentrations[a]	Mean treated waste concentration	Variability factor	Treatment standard
Wastewater				
Mercury (mg/l)	0.0295 0.0284 0.0295	0.029	1.05	0.03

[a] See Table 5-2.

Table 7-2 Calculation of Expected Performance of Cinnabar Ore Roasting Process

Regulated constituent	Accuracy adjusted[a] treated waste concentration (mg/kg)	Mean treated waste concentration (mg/kg)	Variability factor	Expected performance (mg/kg)
Mercury (total) (mg/kg)	45 42.4 36 23 11	31.5	3.49	110

[a]See Table 5-1.

Table 7-3 Calculation of Numerical Treatment Standards for Nonwastewaters

Regulated constituent	Accuracy-adjusted treated waste concentration[a]	Mean treated waste concentration	Variability factor	Treatment standard
Nonwastewater				
Mercury (total) (mg/kg)	0.8 3.1 2.6 7.2 1.6	3.1	5.15	16

[a] See Table 5-1.

Table 7-4 Proposed BDAT Treatment Standard for D009, K106, P065, P092, and U151 Wastewaters

Regulated constituent	Maximum for any single grab sample Total composition (mg/l)
Mercury	0.030

Table 7-5 Proposed Revised BDAT Treatment Standards for K071 Nonwastewaters

High-Mercury Subcategory - Greater than or Equal to 16 mg/kg total mercury	
ROASTING OR RETORTING AS A METHOD OF TREATMENT	
Low-Mercury Subcategory - Less than 16/mg/kg total mercury	
Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 7-6 Proposed BDAT Treatment Standards for K106 and U151 Nonwastewaters

High-Mercury Subcategory - Greater than or equal to 16 mg/kg total mercury	
ROASTING OR RETORTING AS A METHOD OF TREATMENT	
Low-Mercury Subcategory - Less than 16/mg/kg total mercury	
Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 7-7 Proposed BDAT Treatment Standards for P065 and P092 Nonwastewaters

INCINERATION FOLLOWED BY ROASTING OR RETORTING OF INCINERATOR NONWASTEWATER RESIDUALS (ASH AND WASTEWATER TREATMENT SLUDGES FROM TREATMENT OF THE INCINERATOR SCRUBBER WATERS) PROVIDED SUCH RESIDUES EXCEED 16 MG/KG TOTAL MERCURY CONCENTRATION

P065 wastes must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, in specially-designed incinerators. The incinerator ash residual must be processed for mercury recovery using a thermal recovery technology if it does not meet the total composition treatment standard.

P092 wastes must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, or burned in boilers or industrial furnaces in accordance with applicable regulatory standards. The incinerator ash residual must be processed for mercury recovery using a thermal recovery technology if it does not meet the total composition treatment standard.

Table 7-8 Proposed BDAT Treatment Standards for D009 Nonwastewaters

High-Mercury Subcategory - Greater than or equal to 16 mg/kg total mercury

ROASTING OR RETORTING AS A METHOD OF TREATMENT; OR INCINERATION[a] AS A METHOD OF TREATMENT FOLLOWED BY ROASTING OR RETORTING OF THE INCINERATOR NONWASTEWATER RESIDUES (ASH AND WASTEWATER TREATMENT SLUDGES FROM TREATMENT OF THE INCINERATOR SCRUBBER WATERS) PROVIDED SUCH RESIDUES EXCEED 16 MG/KG TOTAL MERCURY CONCENTRATION

[a] Organic nonwastewater forms of this waste must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, or burned in boilers or industrial furnaces in accordance with applicable regulatory standards. Reactive nonwastewater forms of this waste must be incinerated in accordance with the requirements of 40 CFR Part 264, Subpart O, or Part 265, Subpart O, in specially-designed incinerators. The incinerator ash residual must be processed for mercury recovery using a thermal recovery technology if it does not meet the total composition treatment standard.

Low-Mercury Subcategory - Less than 16/mg/kg total mercury

Regulated constituent	Maximum for any single grab sample TCLP (mg/l)
Mercury	0.025

Table 7-9 Proposed BDAT Treatment Standards for D009 and U151
Elemental Mercury Contaminated with Radioactive Materials

AMALGAMATION WITH ZINC AS A METHOD OF TREATMENT

Table 7-10 Proposed BDAT Treatment Standards for D009 Hydraulic Oil Contaminated with Mercury and Radioactive Materials

INCINERATION AS A METHOD OF TREATMENT WITH INCINERATOR RESIDUES MEETING THE FOLLOWING: (1) ASH AND WASTEWATER TREATMENT SLUDGES FROM TREATMENT OF THE INCINERATOR SCRUBBER WATERS MUST COMPLY WITH A TCLP MERCURY CONCENTRATION OF 0.025 MG/L; and (2) SCRUBBER WATERS MUST COMPLY WITH A TOTAL MERCURY CONCENTRATION OF 0.030 MG/L (WASTEWATER STANDARD)

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APPENDIX A

QUALITY ASSURANCE/QUALITY CONTROL DATA

APPENDIX A QUALITY ASSURANCE/QUALITY CONTROL DATA

A.1 Analytical Methods

The analytical methods used for analysis of the regulated constituents identified in Section 5 are listed in Table A-1. SW-846 methods (EPA's Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846, Third Edition, November 1986) are used in most cases, except for the TCLP extraction procedure (published in 51 FR 40643, November 7, 1986, as Appendix I to Part 268 - Hazardous Waste Management System; Land Disposal Restrictions; Final Rule).

Specific procedures or equipment used for preparing or analyzing the regulated constituents when alternatives or equivalents are allowed by SW-846 are listed in Table A-2.

A.2 Accuracy Determination

The accuracy determination for a pollutant is based on the matrix spike recovery values. The accuracy correction factors were determined in accordance with the general methodology (see USEPA 1989a). For example, for most BDAT list metals, actual spike recovery data were obtained for each individual TCLP sample and the lowest value was used to calculate the accuracy corrected value. Table A-3 presents the matrix spike recoveries and the accuracy correction factor used to correct the concentration of mercury in K071 mercury-containing wastewaters.

Table A-1 Analytical Methods

Analysis/Methods	Method
Mercury in Liquid Waste (Manual Cold-Vapor Technique)	7470
Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique)	7471
TCLP	40 CFR Part 268, Appendix I

Table A-2 Deviations from SW-846

Analysis	Method	SW-846 Specification	Deviation from SW-846 Method

[TO BE COMPLETED]

Table A-3 Matrix Spike Recoveries Used to Correct Analytical Data for K071 Mercury-Containing Wastewaters and Untreated K106 TCLP Extract

BDAT constituent	Original amount found (ug/l)	Sample Set #6			Sample Set #6 Duplicate			Accuracy correction factor[b]
		Spike added (ug/l)	Spike result (ug/l)	Percent recovery[a]	Spike added (ug/l)	Spike result (ug/l)	Percent recovery[a]	
Mercury	1.6	4.0	5.4	95	4.0	5.5	98	1.05

NC = Not calculable.

[a]Percent Recovery = [(Spike Result - Original Amount)/Spike Added].

[b]Accuracy Correction Factor = 100/Percent Recovery (using the lowest percent recovery value).

Reference: USEPA. 1988a. Table 6-16.